This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

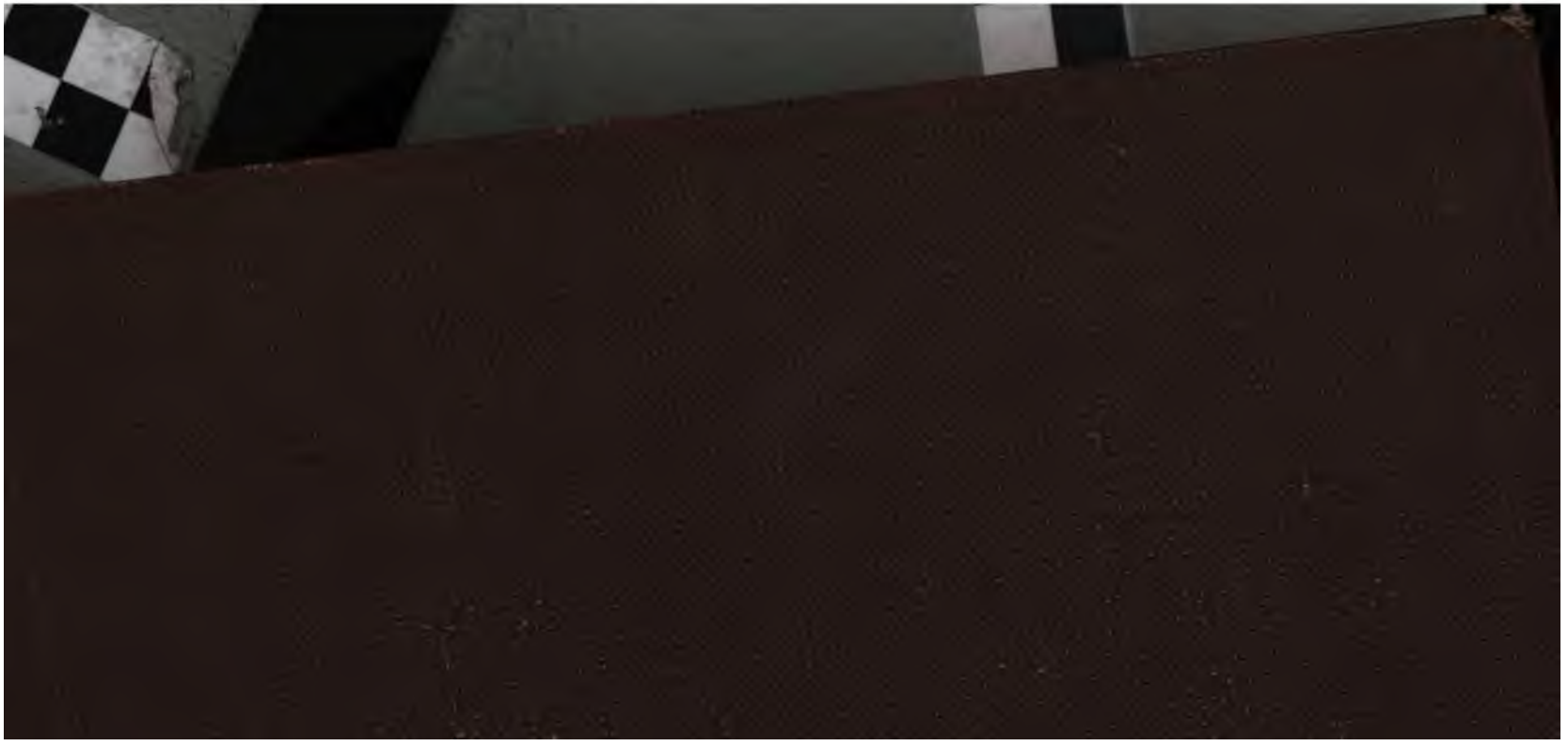
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`



G

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY

OF GLASGOW.

VOL. XVIII.

1886-87.

EDITED BY THE SECRETARY.

STANFORD LIBRARY

PUBLISHED FOR THE SOCIETY BY
JOHN SMITH AND SON,
129 WEST GEORGE STREET, GLASGOW.
1887.

212925

Vol.	IX. (No. 1), ...	Price 2s. 6d.
Do.	IX. (No. 2), ...	,, 3s. 6d.
Do.	X. (No. 1), ...	,, 3s. 6d.
Do.	X. (No. 2), ...	,, 3s. 9d.
Do.	XI. (No. 1), ...	,, 4s. 0d.
Do.	XI. (No. 2), ...	,, 4s. 6d.
Do.	XII., ...	,, 4s. 6d.
Do.	XIII. (No. 1), ...	,, 4s. 6d.
Do.	XIII. (No. 2), ...	,, 4s. 6d.
Do.	XIV., ...	,, 10s. 6d.
Do.	XV., ...	,, 10s. 6d.
Do.	XVI., ...	,, 10s. 6d.
Do.	XVII., ...	,, 10s. 6d.
Do.	XVIII., ...	,, 10s. 6d.

STANFORD LIBRARY

CONTENTS OF VOL. XVIII.

PAGE

I.—On the Development of the Marine Engine. By Henry Dyer, C.E., M.A., ... 1

II.—On Abbe's Apochromatic Micro-Objectives and Compensating Eye-pieces, made of the new Optical Glasses in the Works of Dr. Carl Zeiss in Jena, with some general remarks on Object Glasses. By Adolf Schulze, . . 28

III—On Preliminary Experiments on the Effects of Percussion in Changing the Magnetic Moments of Steel Magnets. By William Brown ("Thomson" Experimental Scholar), Physical Laboratory, University of Glasgow, . . 41

IV.—On a New Tentaculiferous Protozoon and other Infusoria, with Notes on Reproduction and the Function of the Contractile Vesicle. By William Milne, M.A., B.Sc., F.R.S.E., ... 48

V.—On the Manners and Customs of some of the Tribes of New Guinea. By the Rev. James Chalmers, of New Guinea, ... 57

VI.—Report from the Conference of Delegates of Corresponding Societies at the Birmingham Meeting of the British Association, September, 1886. By Henry Muirhead, M.D., LL.D., Cambuslang, ... 70

VII.—On the Progress of Technical Education, with Special Reference to the Glasgow Weaving College. By David Sandeman, ... 73

VIII.—On Coal-gas: and the Coal Question, in its bearings on the Illuminating Power of Gas. By William Key, . 87

IX.—Notes on the Bursting of Leaden Service Pipes by Water and Frost. By George C. Thomson, F.C.S., President, Graduates' Section, Institution of Engineers and Shipbuilders in Scotland, ... 102

X.—On Geographical Alto-Relievo Models, and their place in Education. By William Martin, ... 108

XI.—Graham Lecture.—On certain Modern Developments of Graham's Ideas concerning the Constitution of Matter. By T. E. Thorpe, Ph.D., B.Sc. (Vict.), *F.R.*, C.S., F.R.S., Professor of Chemistry, Royal School of Mines and Normal School of Science, London. Third Triennial "Graham" Lecture delivered before the Society in Anderson's College, 16th March, 1887, ... 118

XII.—An Examination of the Report of the Royal Commission on Depression of Trade: Address inaugurating the Economic Science Section. By Mr. Charles Gairdner, President of the Section, ... 133

PAGE

XIII.—On the Aboriginal Australian, as he was. By Arthur Kay, 146

XIV.—Note on a Class of Definite Integrals. By George A. Gibson, M.A., ... 167

XV.—Some Minor Rights of Land-Ownership. By Archibald Ferguson, Writer, West Regent Street, Glasgow, . 170

XVI.—On Liquid Diffusion. By J. J. Coleman, F.I.C., F.C.S., F.R.S.E., ... 196

XVII.—On the Gothic Version of the Gospels by Bishop Ulfilas, and its Value in the Study of Language. By James Colville, M.A., D.Sc. (Edin.), ... 207

XVIII.—On Approximate Formulæ for the Motion of Projectiles. By Peter Alexander, M.A., ... 237

XIX.—How to use the Polariscope in the Practical Determination of Internal Stress and Strain. By Peter Alexander, M.A., 242

XX.—On a Double Chain of Electrical Measuring Instruments to measure Currents from the Millionth of a Milliampere to a Thousand Amperes, and to measure Potentials up to Forty Thousand Volts. By Sir William Thomson, F.R.S., Past-President, ... 249

XXI.—On the Reform of our Present Methods of Disposal of the Dead: Earth-to-Earth Burial *versus* Cremation. By Eben. Duncan, M.D., President of the Sanitary and Social Economy Section, ... 257

XXII.—On the late Robert Gray, *V.P.*, R.S.E., Corresponding Member. By J. B. Murdoch, F.R.Ph.S.E., . . 279

XXIII.—On the Reducing Action of Hydrogen in the presence of Platinum. By Stephen Cooke, F.C.S., . . . 284

XXIV.—Note on the Action of Electric Sparks on Mixtures of Nitric Oxide with Hydrogen and other Inflammable Gases. By Stephen Cooke, F.C.S., ... 294

XXV.—Note on the Decomposition of Nitric Oxide in contact with Water and Alkaline Solutions. By Stephen Cooke, F.C.S., ... 299

XXVI.—On the Arterial System of Vertebrates homologically considered. By John Mackay, M.D., Senior Demonstrator of Anatomy, University of Glasgow, . . . 302

XXVII.—Note on a Morphological Peculiarity of *Cordyline Australis*. By Professor F. O. Bower, D.Sc., F.L.S., 317

XXVIII.—On *Humboldtia laurifolia* (Vahl.), as a Myrmekophilous Plant. By Prof. F. O. Bower, D.Sc., F.L.S., . . 320

XXIX.—On Biological Teaching in Germany and in this Country. By J. H. Fullarton, M.A., B.Sc., ... 327

XXX.—On the Physical Conditions of the Water in the Clyde Sea-Area. By Hugh Robert Mill, D.Sc., F.R.S.E., F.C.S., of the Scottish Marine Station, . . . 332

XXXI.—Introduction of Sea Water into Glasgow. By John Anderson, ... 357

PAGE

XXXII.—On Foulis' Gas-Fire: A New Departure in using Gaseous Fuel for Domestic Purposes. By the Secretary, . . 365

XXXIII.—An Experimental Research on the Artificial Cultivation of Vaccine Lymph, with observations on the nature of Vaccine and the immunity produced by Vaccinia. By Neil Carmichael, M.D., ... 369

XXXIV.—Automatic Electrical Lighting of Trains. By Thomas P. Carswell, C.E., ... 391

Reports of Sections, ... 397
Minutes of Session, ... 404
Abstract of Treasurer's Account for 1885-86, . . . 406
Account of Graham Medal and Lecture Fund, . . 408
Annual Report of Council for 1885-86, ... 409
Report of the Library Committee, ... 412
Office-Bearers of the Society, ... 432
Committees appointed by the Council. 433
Office-Bearers of Sections, ... 434
Additions to the Library, ... 437
List of Societies and Publications with which Exchanges are made, ... 441
List of Periodicals received, ... 444
List of Members for 1886-87, ... 446
Inventory of Property belonging to the Society, . . 458
Index, ... 459

*** The Editor regrets to say that the publication of Professor Ferguson's two Papers referred to in Vol. XVII. is still deferred.

PLATES.

		PAGE
PLATE	I.—New Tentaculiferous Protozoon and other Infusoria. Mr. MILNE'S Paper, ...	56
PLATE	II.—Liquid Diffusion Apparatus. Mr. COLEMAN'S Paper,	206
PLATE	III.—Facsimile of Gothic Codex Argenteus (coloured). Dr. COLVILLE'S Paper, ...	207
PLATE	IV.—Grimm's Law of Consonantal Change. Dr. COLVILLE'S Paper, ...	212
PLATE	V.—Alphabet: Runic, Gothic, Greek, &c. Dr. COLVILLE'S Paper, ...	214
PLATE	VI.—Cremating Furnace. Dr. DUNCAN'S Paper, . .	278
PLATES	VII. VIII. Arterial System of Vertebrates. Dr. YULE MACKAY'S Paper, ...	316
PLATE	IX.—*Cordyline Australis*. Professor BOWER'S Paper, .	319
PLATE	X.—*Humboldtia laurifolia*. Professor BOWER'S Paper, .	326
PLATE	XI.—Diagram (coloured) illustrating Temperature of Clyde Sea-Area. Dr. MILL'S Paper, ...	356
PLATE	XII.—Introduction of Sea Water into Glasgow: Proposed Route. Mr. ANDERSON'S Paper, ...	364
PLATES	XIII. XIV. Vaccine Lymph Cultivations. Dr. CARMICHAEL'S Paper, ...	388
PLATE	XV.—Automatic Electric Lighting of Trains. Mr. CARSWELL'S Paper, ...	396

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

EIGHTY-FOURTH SESSION.

I.—*The Development of the Marine Engine.* By Henry Dyer, C.E., M.A.

[Read before the Society, 3rd November, 1886.]

From the various accounts which have been published of the origin of the Glasgow Philosophical Society we learn that it was evidently the intention of its founders that one of its chief objects should be the discussion of subjects connected with the improvement of the mechanical arts. In Cleland's account of "The Rise and Progress of the City of Glasgow," published in 1820, we are told that "in 1802 a few gentlemen who had displayed talent and employed capital in the formation and improvement of machinery, by which new facilities were given to manufactures, and the price of labour consequently reduced, formed themselves into a society denominated the Glasgow Philosophical Society;" and in the first published volume of the *Proceedings* it is recorded that certain gentlemen of this city, "considering that general advantage would be derived from the establishment of a society for the discussion of subjects connected *solely* with the arts and sciences, issued a circular, dated 5th November, 1802, to their fellow-townsmen, requesting such as favoured the scheme to attend a meeting on the 9th of the same month." From the record of the "Early History and Proceedings of the Society," by Mr. Keddie, the Secretary, which was published in the fourth volume of the *Proceedings*, it is evident that its chief

business was the discussion of subjects which had a direct bearing on arts and manufactures, and a perusal of the *Proceedings* shows that this was the case until a few years ago.

For some time past, however, papers on mechanical subjects have been somewhat rare. No doubt a good many papers which would have been read before this Society now find their way to the Institution of Engineers. As a member of the Council of that Institution, it is part of my duty to see that it receives a proper supply of papers, but I am of opinion that that supply need in no way interfere with a considerable number of very interesting subjects connected with engineering being discussed by the Philosophical Society. In the Institution of Engineers the audience is composed of men whose chief business is the study or practice of engineering, and who are therefore qualified to enter into the intelligent consideration of technical details. In this Society, on the other hand, the majority of the members have neither time nor opportunity for making themselves acquainted with such details, and the papers read should be of such a nature that any intelligent man may understand them although he has not previously paid special attention to the subject.

I make these remarks in the hope that the department of mechanical science may be more adequately represented in the transactions than it has been for some time past; not, however, at the expense of the other branches of science, because, whatever may have been the original objects of the Society, in my opinion its chief function should now be to keep its members informed respecting the recent advances in all the most important fields of investigation and practice. With the different sections of the Society now fully organised this should not be very difficult to accomplish.

The subject which I have selected for the paper to-night, "The Development of the Marine Engine," is one which ought to interest many of the members who are not engineers, simply because Glasgow has taken such a prominent part in that development, and because it may be considered the cradle, and remains the headquarters of marine engine manufacture. The subject is large enough to require a special treatise, so that all that can be given in a paper of this kind is a mere outline, and those who are acquainted with the design and construction of marine engines are not likely to find much that is new in my treatment of it. The paper is intended chiefly for those whose ordinary work is

not engineering, but I hope I may also make it interesting to engineers, by showing how far theory has guided practice, and how far that practice has reacted on the theory; that is to say, we will consider the marine engine, not in its detailed construction, but simply as an arrangement created by, or at least embodying, a system of principles. Time will not allow us to enter into many historical details of the development of the steam-engine generally, a mere sketch of the earlier applications is all that can be given, and our attention will be chiefly confined to the great improvements which have been made during the past thirty years.

It may interest some of the members to know that this is by no means the first paper which has been read before this Society on the history of the Steam-engine. In 1839 Mr. Hugo Reid read a paper entitled "Remarks on the statements in Arago's Life of Watt regarding the invention of the Steam-engine." At that time the Society did not publish its transactions, but Mr. Reid's paper was so highly thought of by the members that by a unanimous vote they requested him to publish it. Copies of the paper are now extremely scarce, but it was reprinted as an appendix to a small treatise on the Steam-engine by Mr. Reid, and I have no doubt has been read by some now present. The paper was written for the purpose of showing that M. Arago had unduly exaggerated the work done by Frenchmen, especially by De Caus and Papin, in connection with the steam-engine, and had depreciated that of Savary, Newcomen, and Watt. It is not necessary that I should enter into such matters. The few historical details which I will give will be facts which are generally admitted, although I have no doubt critics will be found who will dispute some of them.

A *heat engine* may be defined as an appliance for converting heat energy into mechanical work, and a *steam-engine* is a special form of heat engine in which steam is the working fluid. In studying a steam-engine, however, we may look upon it either as a heat engine or as a machine for doing a special kind of work, and of which the design requires to be adapted to that work. Our time will only permit us to consider the marine engine chiefly from the former point of view.

A *marine engine* is a prime mover, generally a steam-engine (to which form we will confine our attention), which is designed to propel a floating body through water at a certain speed, and although the term is most commonly employed in its correct etymological sense, to denote the kind of engine which is used to

propel ships at sea, it also includes the engines of river boats, and of vessels employed in inland navigation.

In criticising the construction of marine engines, it must be remembered that their design is limited by many conditions which do not hold in land engines, some of which are somewhat contradictory, so that the modern marine engine may be characterised as a collection of compromises, and the manner in which these are effected is a measure of the skill of the designer. The first condition to be noted, especially in vessels intended for long voyages, is that the engines should be economical in the use of steam, and hence of fuel, and that their cost should not be too great. Connected with this condition is another, that the parts should be as light as is consistent with strength and durability. Again, while it is highly advisable that the different parts should be easily accessible for inspection, and repair if necessary, space must be economised as much as possible. The engines must also be easily started, stopped, and reversed, and exert a nearly uniform twisting action on the crank shaft, and be capable of working continuously for long periods without stoppage from any cause. Lastly, it is necessary that their heaviest parts should have as low a position in the vessel as possible, and in war vessels the engines must be under the water line so that they may be protected from the effects of shot. A detailed study of the different classes of engines is necessary before we can see how they fulfil those conditions. All that we can give in the meantime is a brief outline.

Long before steam was used for propelling vessels, paddle wheels had been applied in place of oars. For instance, it is stated that the Roman army under Claudius Caudex was conveyed to Sicily in boats propelled by paddle wheels which were turned by oxen, and illustrations of such boats are to be found in old military histories. Ramelli gives an illustration of a vessel propelled by paddle wheels which were turned by men by means of cranks. The use of the screw propeller seems to have been first suggested by Hooke in 1681.

With regard to the development of the steam-engine, apart from its application to the propulsion of vessels, it will be sufficient to note that in the first engine which was at all of a practical nature, and resembling the steam-engines at present in use, viz., that designed by Papin, the boiler, cylinder, and condenser were combined in one; that the next step was taken by Newcomen,

when he separated the boiler from the condenser; while engines of the same type as those which at present exist were designed by Watt in all their essential details when he separated the condenser from the cylinder, although the tendency to multiply parts still continues, and instead of the steam being used in one cylinder as it was by Watt, it is now very often used in two, three, or more cylinders, each with separate organs of admission and exhaust, and requiring a multiplication of the parts of the mechanism.

In glancing at the history of the application of the steam-engine to marine propulsion, it is not necessary for our present purpose to go further back than the time of Papin, as all earlier attempts seem to be of a somewhat apocryphal nature. In 1690 Papin proposed to use his piston engine to drive paddles for propelling vessels, and some years later he actually constructed a model boat and engine and made some experiments with it on the Fulda at Cassel. The engine was used for pumping water to supply a water-wheel, which, in turn, was made to drive paddles. He, however, failed to obtain the necessary permission from the Government to use the boat, and a mob of boatmen, who thought that if Papin were successful their business would be ruined, attacked the vessel at night and utterly destroyed it. Papin with difficulty escaped with his life and fled to England, and he does not seem to have made any further attempts to establish steam navigation.

In 1736 Jonathan Hulls took out a patent for the use of steam for ship propulsion. In the description which he published of his method, he proposed to use a Newcomen engine, from which a continuous rotatory motion of the paddles was to be obtained by means of a system of ropes and grooved wheels. The vessel was to be used as a tow-boat, but no authentic evidence exists to show that it was actually constructed. In 1752 Bernouilli was awarded a prize by the French Academy of Sciences for the best essay on the manner of propelling vessels without wind. He proposed that what were practically screws should be placed on each side of the vessel, and two more behind, and that they should be driven by animal or steam power.

The great improvements made by Watt on the steam-engine led to a considerable number of attempts to apply it to the propulsion of ships. The earliest seems to have been made in 1763 by William Henry, in Pennsylvania, America, who fitted a Watt engine in a boat having paddle-wheels, and made experiments with it on the Conestoga River. A considerable number of inventors

appeared in America shortly after this date. Of these, John Fitch and James Rumsey are the two whose names are the most prominent, and who, after several trials with their boats, were able to obtain a speed of seven miles an hour. The engines were Watt beamed engines, and they were employed in driving paddles which at first were placed amidships, but latterly at the stern. In 1796 Fitch made some experiments with a small screw steamboat.

In France, between the years 1720 and 1783, the Marquis de Jouffroy and others made experiments very similar to those of Fitch, but the Government refusing to grant a monopoly, which had been promised, they were compelled to abandon them.

In Scotland, in 1788 and 1789, Miller of Dalswinton, Taylor, and Symington made experiments with paddle boats, but they appear to have failed chiefly on account of the imperfect nature of the means employed for transmitting the motion of the piston to the propeller. Symington, however, in 1801, taking advantage of Watt's improvements, designed a vessel, the *Charlotte Dundas*, with a paddle-wheel near the stern, and driven by a direct-acting horizontal engine with a connecting rod and crank. This vessel was successfully employed as a tug on the Forth and Clyde Canal, but the directors, fearing injury to the banks of the Canal, abandoned its use.

About the same time Fulton and Stevens made successful experiments in America with small paddle steamers, and to the former is largely due the honour of the successful introduction of steam navigation into his own country, for, after many trials, he was able, in 1807, to design and build the *Clermont*, which may be considered the first steamer which was successful, from a commercial point of view, that is to say, which remunerated its proprietors for the expense which they had incurred. It was propelled by paddles driven by an engine made by Boulton and Watt, and had many of the characteristics of the American river steamer of the present day.

In this country the corresponding step to that made by Fulton in America was made by Henry Bell in 1812, when he designed the *Comet*, which was built to run between Glasgow, Greenock, and Helensburgh. The boat was constructed by John Wood of Port-Glasgow, and the engine was made by John Robertson of Glasgow, and was essentially an inverted beam or side lever Watt engine, and the power was transmitted to two pairs of paddles by means of spur gearing. This arrangement, however, proved unsatisfactory,

and the boat was lengthened and the original engine replaced by a larger one which drove a simple pair of paddles; and by these means a speed of about six miles an hour was realised. The *Comet* plied to various places for several years, and was wrecked at Craignish in 1820.

Since Fulton and Watt's time, the changes which have taken place in the marine engine have not consisted so much in the development of new principles as in modifications of form and design and improvements in workmanship, with consequent economy of fuel. As my present object is not to sketch the progress of steam navigation (which, however, I may do in a future paper), but simply to note some of the chief points in the development of marine engines, it will be sufficient to mention shortly some of the general designs which have been made, and of the chief details which have rendered the engines more economical.

Marine engines may be divided into three classes, according to the nature of the propelling apparatus, which always requires a special arrangement of engine. In the first class we have paddle engines for propelling the vessels by means of paddles, as already explained; in the second, screw engines for propelling the vessels by means of screws or twisted vanes revolving beneath the water at the stern; and in the third, we have engines for working pumps which propel the vessels by means of the reaction of a jet of water. This last class, although it doubtless has a great future before it, can scarcely be said to have come into the sphere of practical engineering, as very few such engines have been made, and as at present we have not time to speculate on what may be done, but simply to review what has been done, it will be sufficient if we confine our attention to the two first classes.

The inverted beam, or side-lever engine, was for many years chiefly used for the larger marine engines. Engines of this class were not by any means self-contained, the keelsons and framing of the vessels being largely relied upon for resisting the stresses arising from the action of the engines; and, of course, under such conditions, a low pressure of steam and steady uniformity of motion were matters which were essential to their safe working, and the makers of such engines seemed to exercise their ingenuity on their architectural details, rather than on the proper disposal of the metal for resisting the forces which acted on their various parts. There can be no doubt, however, that so far as external appearance went, some of the side-lever engines were grand

specimens as compared with the bold and strictly utilitarian designs of the present day, and at the same time were very powerful and fairly efficient, considering the state of steam-engines generally at that date. Being employed in propelling paddles, their crank shafts were on a level with the deck; a pressure of steam of about 10 pounds on the square inch was used, and the space occupied in the hull by the engines and boilers was nearly one-third of the ship's length. Engines of the side-lever type have now entirely disappeared, although, even at the present day, ordinary beamed engines are largely used in American river and coasting steamers, and with their long strokes and steady motion hold their own against the modern types.

Many modifications of the side-lever engine were designed, and in some cases horizontal engines were used, for driving the paddles, but these were objectionable on account of the great weight they caused to be placed on the deck. To obviate this the steeple engine was designed by Mr. David Napier in 1836, and continued in use for many years, especially in river steamers. It is now, however, seldom made, the direct-acting diagonal or the oscillating engine (which was first designed by Penn in 1837), being generally employed for paddle steamers.

When the screw-propeller was first introduced, and for a considerable time thereafter, the same kinds of engines were used for driving it as were employed for paddle vessels, the connection between the crank and the propeller shafts being effected by means of gearing. Now, however, the screw-propeller is almost always driven directly from the crank shaft, and the most common types of engines employed are the horizontal and the vertical, the former in the navy, in which it is necessary that the machinery should be below the water-level, the latter in the mercantile marine. In each of these classes we find single-cylinder engines, but generally speaking compound engines of some form are used, the two-cylinder type in many cases; but in recent years triple and quadruple expansion engines have been introduced with good results.

The improvement which has been made in the efficiency of marine engines considered as heat engines has been brought about chiefly by the increase of the pressure of the steam used. Watt not only confined his practice to steam a little over atmospheric pressure, but he did all in his power to prevent the introduction of the high-pressure engines designed and constructed by Trevithick and others. He was quite aware that the efficiency of the steam was increased by

raising its temperature, his chief reason for objecting to the high-pressure engines being that he feared the danger which would attend their use. Influenced, no doubt, by Watt's example, the progress of high-pressure steam was very slow; and as late as 1839 the greater part of the evidence given before a Parliamentary Committee seemed to show that the only use of high-pressure steam was to dispense with condensing water, and as there was always plenty of water in the neighbourhood of a steam-boat, such steam was unnecessary for a marine engine. It was not till after Joule and others had determined by experiment the value of the dynamical equivalent of heat, and Thomson, Rankine, and Clausius, taking advantage of these experiments, had developed the mathematical side of the subject, and put it into a form intelligible to engineers, that the pressure of steam was increased to any great extent. Even then it is not clear whether the increase arose from a distinct recognition of the law of efficiency of heat engines, namely, that the real value of heat as a source of mechanical power depends on the temperature of the working substance relatively to that of surrounding bodies, and consequently that high-pressure engines derive their advantage over low-pressure engines from their power of making useful a greater range of temperature, or whether it was simply from greater confidence in the use of steam and of the materials used in construction. In any case, from the date of these investigations, the pressure of steam used in marine engines was gradually increased until it reached from 30 to 40 lbs. on the square inch. When it had risen to the latter figure, and considerable expansion was employed, the variation in the temperature of the cylinder caused a large amount of initial condensation of the steam, followed by a certain amount of re-evaporation towards the end of the stroke. In engines working under such conditions, if we compare the weight of steam actually used with that obtained by multiplying the volume moved through per stroke of the piston by the density of the steam, it is found that the former is always much greater than the latter. This difference was formerly accounted for by supposing that steam escaped past the piston; but the researches of D. K. Clark in this country, Isherwood and others in America, and Hirn, Leloutre, and Hallawer on the Continent, have fully explained it by the action of the sides of the cylinder on the steam. In the theory of the action of steam-engines, as developed by Rankine and Clausius, no account is taken of the action on the steam of the materials of which the cylinders

are constructed, and hence that theory has to be viewed in the light of experiments with actual engines. This had, in fact, been done to a certain extent a hundred years before this date by Watt and Smeaton; but its systematic investigation for the conditions under which steam is now used in engines is due to the men I have named, who showed that between the sides of the cylinder and the steam, or rather the mixture of steam and water, there is a continual exchange of heat. When the steam enters the cylinder a considerable part of it is condensed against the sides, which become covered with a film of water. During expansion heat is restored to the condensed steam, and the film of water re-evaporates either partially or wholly. With low rates of expansion the temperature of the internal surface of the cylinder is higher than the exhaust temperature, while with high rates the temperature during expansion is so much reduced that when fresh steam enters at the beginning of the next stroke a large quantity is condensed which is not all re-evaporated during expansion, and on the communication to the condenser being opened at the end of the stroke it is suddenly evaporated and passes into the condenser without doing useful work—a cause of loss of efficiency which increases with the pressure and ratio of expansion. Hence arose the necessity for compound engines, in which the steam is used successively in two cylinders. To John Elder is largely due the honour of having successfully applied such engines for marine purposes. He, moreover, re-introduced the steam jacket invented by Watt, but which had gone wholly out of use in marine engines, and he was thus able to prevent a considerable amount of the initial condensation as well as that caused by the expanding steam doing work. This latter part of the condensation was foretold by Rankine and Clausius from theoretical grounds, but neither of them seems to have recognised clearly the condensing effect of the sides of the cylinder. We cannot examine the claims of all who took part in the development of the compound engine, but other two Glasgow names deserve to be mentioned, namely, Charles Randolph, who was associated with Mr. Elder, and J. M. Rowan. The latter deserves much credit for his persevering efforts to introduce high-pressure steam and surface condensation, and to convince engineers and shipowners of the advantage that attended their use, and that the practical difficulties were generally due to defective constructions, which could be avoided.

A great increase in the efficiency of marine engines was the

immediate result of these improvements in their design, and the steam pressure went up to 80 and in some cases to over 100 pounds on the square inch. It is doubtful whether saturated steam at a higher pressure than the first-named of these figures can be used with economy in a two-cylinder compound engine, for beyond that pressure we have a recurrence of the evils found in simple engines. This has led to triple expansion engines, in which the steam is expanded successively in at least three separate cylinders, and such engines form the most important development in marine engineering which has taken place during the past few years. Generally speaking, steam of a boiler pressure of about 150 lbs. on the square inch is employed. Being admitted into the first or high-pressure cylinder, it is cut off at about three-fourths of the stroke and allowed to expand; it then passes into the mean-pressure or middle cylinder, in which the volume is much greater than that of the high-pressure cylinder, and there expands as in the low-pressure of an ordinary compound engine; and from that it passes into a third cylinder of much greater capacity, where it is still further expanded; and lastly it escapes into the condenser. Such is the most common arrangement, but many triple expansion engines have four cylinders. In these the third expansion takes place in two cylinders simultaneously, instead of in one larger low-pressure cylinder. Others again have six cylinders—one high-pressure, two mean-pressure, and three low-pressure cylinders—an arrangement which is very suitable for large powers. Many other arrangements might be suggested, but into the consideration of these we need not enter, our object being not to study different designs, but to explain shortly the principles on which they all act and the reasons why their economy is greater than that of engines which had been previously made.

Triple expansion engines are the natural development of the ordinary compound engine, and, as at present constructed, have been evolved from the practice of many engineers. French writers on engineering claim that triple expansion engines were first designed in France. If they were, the results were evidently not very satisfactory, as little progress was made. In this country the earliest application of the principle seems to have been made by Messrs. John Elder & Co. in 1874, in the case of the engines of the *Propontis*, which were designed by Mr. A. C. Kirk. In these engines a pressure of 150 lbs. on the square inch was employed. They had three cylinders of progressive capacities, the smallest

being the high-pressure to which the steam was first admitted, next the intermediate one to which the steam passed from the high-pressure, and the third the low-pressure, receiving the steam from the intermediate cylinder and discharging it into the condenser, each cylinder being placed above its own crank in a three-throw crank shaft. The boiler employed was of the water tube type, and gave so much trouble that it was taken out and replaced by an ordinary internally-fired boiler, carrying a pressure of 90 lbs. to the square inch. The original engines of the *Propontis* are, however, still at work. For some years after the date named little progress was made in the increase of steam pressure and the construction of triple expansion engines. M. B. Normand of Havre, Mr. Taylor of Newcastle, Messrs. Douglas & Grant of Kirkcaldy, and one or two others constructed comparatively small engines of this type for passenger boats and yachts. Herr F. Schichau of Elbing, in Germany, commenced in 1877 to construct triple expansion engines for torpedo boats, and between that date and the present time he has made more than 100 sets of such engines. Herr Schichau evidently thinks he can compete with British engineers in the construction of the smaller class of marine engines, and deliver them in Britain at a price which would not yield a profit to British manufacturers. I am not able to give a comparison of his prices with those of Clyde engineers, but the mere fact of the appearance of Herr Schichau's advertisements in British journals is sufficient to give our engineers ground for serious thought. The other day, in a German technical journal, I saw an article claiming for Herr Schichau the credit of the invention of the triple expansion engine. The claim was based on the supposition that he was the first, in 1877, to make triple expansion engines with three cranks, but as I have already pointed out, the *Propontis* had been constructed on this principle three years previously. Whatever dispute there may be about these first attempts, it cannot be denied that the successful introduction of the triple expansion engine into the mercantile marine is due to the designer of the engines of the *Propontis*, when in 1881, as senior partner of Messrs. R. Napier & Sons, he designed and constructed the engines of the *Aberdeen*. These engines are essentially of the same type as those of the *Propontis*, the cylinders being 30 in., 45 in., and 70 in., by 4 feet 6 in. stroke. The boilers, two in number, are ordinary double-ended boilers, constructed entirely of steel, with six of Fox's corrugated furnaces in

each; and the pressure of steam is 125 lbs. on the square inch. These engines being highly successful, a great impetus was immediately given to the construction of triple expansion engines. We need not enter into details: it will be sufficient to state that at the beginning of this year 142 sets of such engines had been built, and 100 were being built in Britain, and also that on the Continent they were making considerable progress. It is satisfactory to know that Clyde engineers keep the lead in the manufacture of such engines, of which sufficient proof is afforded by the fact that at present there are in the workshops of Messrs. Napier & Sons triple expansion engines of the aggregate of about 36,000 indicated horse-power—the largest set of 13,000 horse-power, it may be remarked, being for the Russian navy, another fact which is worthy of very serious consideration, not, however, in this case particularly by British engineers, but by the British public generally. Britannia is said to rule the waves. If she wishes to retain that sovereignty she must keep her eyes open as to what is being done by those who would dispute it with her if they thought they had any chance of success.

We know from the principles of thermodynamics that the efficiency of a perfect heat engine is given by the expression—

$$R = \frac{T_1 - T_2}{T_1} = \frac{T_1 - T_2}{T_1 + 461{\cdot}2} = \frac{T_1 - T_2}{T_1 + 274}$$

—the first form of the expression being in absolute degrees of temperature, and the last two in Fahrenheit and Centigrade degrees, respectively. Translated into words, this expression means that the law of efficiency is—that the heat converted into mechanical work is to the whole heat received as the range of temperature is to the absolute temperature at which it is received. We may increase the range of temperature either by raising the temperature at which the heat is received or by lowering that at which it is rejected. Various attempts have been made with this latter object in view, but for all practical purposes we may consider the temperature of the condensing water as the lower limit. This is generally about 104° F., or 40° C. The lower limit being thus fixed, the only thing left is to increase the initial temperature. This can be done either by directly superheating the steam, or by increasing the pressure and thus also raising the temperature. When steam of low pressure was employed in marine engines it was not unusual to superheat it to a considerable degree above the

temperature corresponding to the saturated condition; but, now that higher pressures have become common, superheating has been almost entirely abandoned, and further economy is now attempted chiefly by raising the pressure of the steam, and increasing the number of cylinders in which it is used. The difficulties, or supposed difficulties, in the way of the use of superheated steam have hitherto prevented its application to any great extent; but, as we now seem to have almost reached the limit of the improvement of engines working with saturated steam, a still further improvement would be obtained by moderate superheating, if engineers seriously took the matter up. My object at present is, however, not to speculate regarding future improvements, but rather to explain present practice.

Experience very soon shows us that the law of efficiency of perfect heat engines, can only be applied to actual engines with very considerable limitations, as various causes prevent the advantages of high pressures being available, and that, even beyond a certain point depending on the type of engine employed, such pressures are disadvantageous. Experiments show that the economy of steam-engines does not necessarily increase with the increase of the pressure of the steam, and of the rate of expansion, and that expansive working often means expensive working. When the pressure remains constant and expansion is augmented, at first there is a diminution in the consumption of steam, then it increases, and for each pressure there is ratio of expansion which gives the maximum efficiency; and it may be stated generally that in all classes of engines the efficiency depends not only on the *amount* but also on the *method* of the expansion.

We have already seen that this is accounted for by the action of the sides of the cylinder on the steam, and that in a single-cylinder engine using moderately high-pressure steam and considerable expansion, the re-evaporated steam passes into the condenser without doing useful work; and further, that in ordinary compound engines this is largely utilised behind the low-pressure piston. Even in the latter class of engines there was considerable amount of loss from the re-evaporated steam not being efficiently used, and when pressure rose above 80 lbs. on the square inch all the evils of the single engine began to reappear, and the compound engine required to be compounded; that is to say, triple expansion engines became necessary. In these the fall in the temperature is divided among three cylinders, the amount of condensation in each is

reduced, and what takes place is to a large extent utilised during re-evaporation behind the pistons of the mean and the low-pressure cylinders. For higher pressures and grades of expansion than those employed in triple expansion engines, quadruple or even higher expansion engines may become necessary. As, however, the rate of the increase of temperature of saturated steam decreases as the pressure increases, and as the cost of the construction of engines increases with the pressure, a point must soon be reached when the increase of efficiency of the steam will be balanced by the increase of cost, and by the loss of efficiency of the mechanism from increased friction—in other words, when theoretical efficiency is balanced by practical losses. This point can only be determined by practical experience.

It will be observed, then, that the triple expansion engine is simply an arrangement for diminishing waste of energy by counteracting, as far as possible, the effects of the sides of the cylinder on the behaviour of the steam. The study of its action shows how necessary it is to understand under what conditions the received laws of thermodynamics hold in practice, especially that relating to the efficiency of perfect heat engines, as well as the deductions made from it as to the use of high pressures and rates of expansion. Again, we are often told in the ordinary text-books that in a compound engine the work done in a stroke depends on the size of the large cylinder, and is the same as would be done in a single cylinder of the same contents by expanding to the same amount from a like initial pressure. A statement like this, without further explanation, is of the nature of a half truth, which is worse than an error, for it conceals the truth. If it were literally correct for actual engines, what would be the necessity for ordinary compound, far less for triple or quadruple expansion engines? We have seen why it is necessary in using high-pressures to divide the expansion into a number of parts in separate cylinders, proportionally to the pressure. When we look at the steam-engine as a heat engine, we are placed in a dilemma between the teachings of the laws of thermodynamics, as usually stated, and of experience. With low-pressure steam in an engine with a single cylinder, we have low initial temperature and consequently low efficiency. On the other hand, if we attempt the use of high-pressure steam with considerable expansion in such an engine, we have a great amount of waste; and, consequently, we are compelled to increase the number of cylinders in which the

steam is used—an increase, as we have seen, which is limited by questions of cost of construction and efficiency of mechanism.

The use of the steam jacket seems to have varied more according to the fancies of constructors than from clear notions of its action.* It was, as I have already remarked, designed by Watt, but it is not known what ideas he held as to its effect, as he published no reasons for using it, except that of keeping the steam as hot as possible. His immediate successors certainly did not understand it, the general opinion evidently being that it only served to prevent radiation from the external surface of the cylinder, and as the jacket presented a greater surface than the cylinder, reasoning from the caloric hypothesis they inferred that it was not only unnecessary but wasteful, and its use was abandoned to a great extent in land engines, and entirely in marine engines. As I have further remarked, to John Elder is due the honour of having reintroduced the use of the steam jacket in the latter class of engines, and he was thus able to prevent a considerable amount of the initial condensation as well as that caused by the expansion of the steam.

The beneficial effect of the steam jacket arises from the fact that it prevents condensation of the steam in the cylinder by imparting heat to it through the sides of the cylinder, thus causing condensation to take place in the jacket, where the pressure is constant, instead of in the cylinder, where it is variable. Its action is, however, more complicated than is generally supposed. It not only prevents or lessens the condensation of the steam, which would be caused by the external work done, but it also modifies in a great degree the action of the sides of the cylinder by reducing the condensation during admission and increasing the evaporation during expansion. The advantage from the use of the steam jacket varies according to the circumstances under which it is employed, and in some cases, as, for instance, when low rates of expansion are used, the jacket may not only be useless but wasteful. On the other hand, when high rates of expansion are used, by preventing the temperature of the cylinder from falling much below the boiling point, corresponding to the initial pressure of the steam, the economy resulting from the action of the jacket is considerable, the work developed by the engine being increased by an amount varying from 15 to 25 per cent. of what would be developed

*See Paper by Author, Trans. Inst. Eng. Scot., 1885.

without the jacket. But, contradictory as it may seem, the use of the steam jacket (as ordinarily constructed) is a violation of the fundamental law of maximum efficiency of heat engines, which requires that they should receive all their heat at the maximum and give it out at the minimum temperature, and not as in the case of an engine with a steam jacket some of it at temperatures between these, and at times when the heat imparted lessens the efficiency, which it evidently must do at and near the end of the stroke. The steam jacket must thus be looked upon as a necessary evil, justified only by the physical properties of the steam and of the materials hitherto used in engines, for, while it increases the work done by the expanding steam, the increase is by no means so great as it would be if the heat employed in the jacket steam had been applied to generate more steam for use in the cylinder. Hence, in multiple expansion engines, in which the variation of temperature is not very great, steam jackets have either been wholly or partially omitted. For instance, in the *Aberdeen* the high-pressure cylinder is not jacketed, the second is jacketed with steam of 50 lbs. pressure, and the low-pressure one with steam of 15 lbs. above the atmosphere. There can be no doubt that if the jacket were always kept in good order it would be an advantage to have it on all the cylinders; but at sea it is extremely doubtful whether jackets do not very often do more harm than good, simply because they are not kept in proper order. Apart from their primary use, jackets are very convenient for heating up the cylinders on starting, and as the liners are now always cast separate from the exterior casing they have the further advantage of convenience of renewal when the interiors of the cylinders become worn.

There is a considerable amount of variation in the proportions of the cylinders of multiple expansion engines. The objects which the designer ought to keep in view are to divide the power exerted evenly between the cylinders, and to avoid as much as possible drop of pressure when the steam is passing from one cylinder to another, as well as high initial pressure on the cranks. There are a number of variables in the problem, such as initial pressure, total ratio of expansion, and degree of admission of steam in the high-pressure cylinder, and a great deal depends on the judgment of the engineer. For ordinary compound engines the ratio of the contents of the cylinders generally varies from $3\frac{1}{2}$ to 4; and of

about forty triple expansion engines the following are the mean proportions:—

H.P. to M.P.	M.P. to L.P.	H.P. to L.P.
2·60	2·88	7·33

—and the total ratio of expansion varies from 8 to 12.

There are many different ways of arranging the cylinders, some of which have been already mentioned. The main thing to be kept in mind from this point of view is to insure that there shall be nearly uniform twisting moments on the crank shaft. The three-throw crank seems the best suited for this object, and, as already mentioned, for moderate power the type of engines used in the *Aberdeen*, with each cylinder over its own crank, is the best. For great powers, however, it would not be advisable to employ this type on account of the unwieldy dimensions the low-pressure cylinder would attain; and a great many other arrangements are possible from which the designer must select, according to the special conditions of the engine under consideration, as no general rule can be laid down which is applicable to all cases.

The use of high-pressure steam in marine engines was retarded for a considerable time by the difficulty of preventing a large deposit of lime in the boilers, as it was found that when the pressure had risen to over 30 lbs. on the square inch no amount of "blowing out" would prevent a deposit which soon became dangerous. The surface condenser, although its use at first presented some difficulties, has prevented the precipitation of much deposit, and made the employment of steam at the highest pressures we have named possible. Its first application to marine engines was made by Samuel Hall in 1837, but for more than 20 years after that date it made little progress. Between 1860 and 1865 a sudden demand arose for surface condensing engines. By that time the inverted direct-acting marine engines had become the favourite with shipowners and engine-builders. In these the condenser was at first formed by two of the columns to which the air-pumps were fitted. The surface condenser, however, required greater space, and to provide this the condenser box was attached to one set of the columns, on the interior face of which the guides are fitted.

I have mentioned that Watt opposed the use of high-pressure steam, not because he was ignorant of the increase of efficiency

which would result from it, but because he had not sufficient confidence in the materials used in the construction of boilers and cylinders to withstand the pressure, and that no doubt his example had a great effect in retarding the introduction of high-pressure steam, as men did not exert themselves to ascertain whether his opinions were justified, or if they were to improve the manufacture or design of the parts exposed to pressure. For many years the marine boiler contained large flat surfaces all of which required staying, and they were only suitable for pressures not exceeding 30 lbs. on the square inch. For the high pressures now in common use some form of the cylindrical boiler is generally employed. For engines not exceeding 500 I.H.P. the single-ended boiler, made with two, three, and sometimes four furnaces, is generally adopted, while for larger sizes the double-ended boiler is chiefly used, and is found to be more economical than the single-ended one. Many other modifications and special designs have been proposed, but into these we need not enter, except to mention the locomotive type, which is generally employed for small engines, such as those made for gun and torpedo boats, in which it is necessary to reduce the weight of the boilers and of the water in them, as well as to get a large power out of a small boiler. The tubes afford a large amount of heat-absorbing surface, and the fire-box is very efficient. The great improvements which have been made on the manufacture of steel and on the manner of treating it have enabled engineers to produce boilers which are strong enough for the highest pressures yet employed, without departing much from the shapes which were used for lower pressures, and which have the advantage of simplicity of construction and convenience for repairs. In order to increase the efficiency of boilers, many attempts have been recently made to produce an artificial draught, and there can be no doubt that when these are properly designed and carried out there is considerable economy of fuel. Into the details of these methods, as well as the improvements in the mechanism and propellers, want of time will not allow us at present to enter.

Having now made a rapid resumé of the progress of the development of the marine engine, I will glance shortly at a few of the results obtained. The most exact method of measuring the efficiency of a steam-engine is to ascertain the number of units of heat expended per indicated horse-power; or, since the total heat of evaporation does not increase rapidly with the increase of pressure, we may take the weight of steam used per indicated

horse-power instead of the amount of heat. This is, of course, obtained by measuring the amount of feed-water, and for land engines many experiments of this kind have been made. The difficulty of making such experiments with marine engines is so great that, as a rule, their efficiency is generally measured by the weight of fuel consumed per indicated horse-power per hour. In Smeaton's early engines the consumption of coal was nearly 30 lbs. per indicated horse-power per hour; in his later ones it was reduced to about 18 lbs. Watt is said to have begun with 8·3 lbs., and to have gone on to 2·7 lbs. These figures, of course, all relate to land engines. The old side-lever marine engines, with a pressure of about 10 lbs. on the square inch, consumed about 7 lbs. of coal per indicated horse-power per hour. For engines working with a pressure of 30 lbs. on the square inch, that is to say, almost all engines employed about 1863, the consumption of coal was somewhat over 4 lbs. per indicated horse-power per hour, a figure which might be taken to represent the average for simple marine engines. In 1872, when two-cylinder compound engines had been in use for some years, it was found by Mr. Bramwell that the average of 19 ocean steamers was about 2·11, being a saving of nearly 50 per cent.; and in 1881 Mr. Marshall found that the average of 30 steamers was 1·828 lbs., or a further saving of 13·37 per cent., while in the triple expansion engines which have been introduced within the past three or four years, the consumption has been found to be as low as 1 or 1¼ lbs. The following statement, which was recently made, will show the economy of triple expansion engines in a more striking light:—"Two large passenger steamers of over 4,500 gross tonnage, having engines of about 6,000 indicated horse-power, built of the same dimensions, from the same lines, with similar propellers, are exactly alike in every respect, except so far as their machinery is concerned. One vessel is fitted with triple expansion engines working at a pressure of 145 lbs. per square inch, whilst the other vessel is fitted with ordinary compound engines, working at a pressure of 90 lbs. per square inch. Both vessels are engaged in the same trade, and steam at the same rate of speed, viz., 12 knots per hour. The latter vessel on a round voyage of 84 days burns 1,200 tons more coal than the former." It is needless to multiply special cases, as they would all show that triple expansion engines, with steam of 150 or 160 lbs. on the square inch, use from 20 to 30 per cent. less fuel than in equally good ordinary two-cylinder compound engine of equal

power, and working under similar circumstances with steam at 90 or 100 lbs. absolute pressure.

However, the following remarks by the President of the North-East Coast Institution of Engineers and Shipbuilders will give some idea of the magnitude of the question of economy of fuel in steamships. Speaking of the mercantile marine, he said, "He would for convenience divide the present fleet into three classes, that thus we might arrive as nearly as possible at a knowledge of its present condition, and that the shipowner might realise his position and what he had to face to put his fleet in order, and the shipbuilder and engineer might know the work that lies before them. The first class included all boats of modern type, and which might be thought fairly capable of earning profits for some time to come, although not fitted with triple expansion engines. In the second class he included those boats which must be re-engined, or have their engines altered to triple expansion to give them any chance of competing favourably with the more modern type of boat. In the third class were those boats which he considered obsolete and not worth the cost of altering. For the first class he took all boats built since 1880, although there are comparatively few of them with triple expansion engines, say 3,006, amounting to 4,321,137 tons; then of those boats built from 1876 to 1880 he took one-half as being fairly economical and not needing to be altered at present, say 791 boats, amounting to 952,709 tons; giving a total of 3,797 boats and 5,273,846 tons. For the second class he took the balance of the boats built from 1876 to 1880, all boats built from 1871 to 1875, and 25 per cent. of those built from 1866 to 1870, making a total of 2,573 boats, amounting to 3,089,536 tons. For the third class he took the balance of those built from 1866 to 1870, equal to 75 per cent., and all before 1866—making a total of 1,519 boats and 1,492,178 tons. After remarking that these figures were, of course, only approximate, he went on to say that it was with the second class he proposed to deal. He wished to arrive approximately at the amount of work to be done to those 2,573 boats, and the cost of doing it. If only one-half needed to have new engines and high-pressure boilers, that would give, say, 1,286 boats, with a gross tonnage 1,544,768, which he estimated would cost for engines and boilers £5,000,000; shipwork, probably £1,000,000; cost of altering the engines of the other 1,287 boats, including new boilers, say, £3,000,000; shipwork, say, £500,000—a total of £9,500,000. If he were

correct in his premises and deductions, this amount of £9,000,000 should be spent at once on these 2,573 boats, or they would have no chance of competing favourably with other boats." The question was, "Would it pay?" He then said:—"I estimate the engine power of these 2,573 boats to be 1,730,000 horse-power, and taking the consumption at 2½ lbs. per horse-power per hour, and allowing 250 steaming days in the year, we have a total consumption of 11,585,000 tons of coal; but let us reduce this to 10,000,000 tons, for steamers do not always run at their full power, and then, if we take a saving of only 20 per cent. for the triple expansion engines, we have a saving of 2,000,000 tons of coal per annum, which may be taken on the average as worth 20s. per ton. Now, to estimate the true advantage to be gained by adopting triple-expansion engines and high-pressure boilers, we must deduct from the estimated cost of £9,500,000 the amount which must necessarily be spent on new boilers and shipwork whether the engines are altered or not, and this we cannot put at less than £3,500,000, for it is notorious that many steamers can hardly go to sea again without new boilers or a general overhaul, and that the great bulk of the steamers I am now dealing with must have very considerable sums spent upon them within a very short time. This estimate leaves a balance of £6,000,000 as the cost of adopting triple expansion engines, against which we have a saving in fuel of £2,000,000; also a saving in wages, as there would be 2,000,000 fewer tons of coal to handle—surely a good return for the sum expended." I do not quote those figures for the purpose of endorsing the details of the proposals made, but simply to give some idea of the amount of saving which would result if all the marine engines at present in use were of the most economical type.

The weight of the engines and boiler on board a ship has a considerable influence on its commercial efficiency, or the profits which it yields to its owners, so that it is not sufficient to consider economy of fuel by itself, for if that is obtained by a sacrifice of space or a great additional weight the commercial efficiency of the ship may be reduced. It is stated that every ton of deadweight capacity is worth on an average £10 per annum for earning freight, that is to say, that every 100 tons saved from the weight of the engines and boilers, without increasing the cost of working, is equivalent to £1000 a year additional income to the owners. It is difficult to get exact figures showing the relation of weight of machinery, including engines, boilers, water, and all fittings ready for sea, in

pounds per indicated horse-power, but the following figures by Mr. Marshall of Newcastle give a near approximation :—

	Lbs. per I.H.P.
Merchant Steamers, ...	480
Royal Navy, ...	360
Engines specially designed for light-draught vessels,	280
Royal Navy, "Polyphemus" class, ...	205
Modern Locomotive, ...	140
Torpedo Vessels, ...	60
Ordinary Marine Boilers, including water, ...	196
Locomotive Boilers, including water, ...	60

Mr. Marshall adds—"In view of the commercial considerations before mentioned, in regard to merchant steamers, these figures confirm the idea that the weight of machinery on board such vessels has not received the attention its importance demands."

The weight of marine engines may be decreased by improving their efficiency as machines—that is to say, by increasing the ratio of the indicated horse-power to the effective power given off at the crank. This is done by reducing the friction of the moving parts. Unfortunately, we know little of the efficiency of marine engines considered as machines by direct experiment, and it is to be feared that some of the apparent economy derived from recent improvements in the use of the steam is spent in overcoming the friction or internal resistance of the mechanism. As we have seen, the ordinary method of measuring the performance of a marine engine is by ascertaining the weight of fuel used per indicated horse-power per hour; and this includes a measure of the economy not only of the engine as a heat engine, but also of the efficiency of the boiler and of the mechanism, the quality of the fuel and the ability of the fireman, and no direct measurements are made of the actual power given off at the crank shaft. Some of the modern forms of marine engines are well designed for reducing the amount of work spent in friction, but in others the point is very much overlooked, and if experiments were made to determine their efficiency their makers and owners would be very much startled at the results. We might have two engines using the same amount of fuel per indicated horse-power per hour, but if the efficiency of the mechanism of the one was much greater than that of the other, the actual horse-power of the two engines would be very different. The modern marine engine is in such a stage that the comparison of ordinary compound with triple or quadruple ex-

pansion engines in the manner in which it is usually done is very apt to lead to wrong conclusions, as we require, in addition, tests of the efficiency of the mechanism.

Increased piston speed is another characteristic of the modern marine engine which leads directly to economy of weight in the engines, as the power developed is proportional to the speed of the piston, and as the weight is not affected by the increased speed to any great extent. In the early marine engines from 150 to 200 feet per minute were the average piston speeds; now from 600 to 800 feet per minute are common. In order that high speeds may be safely and economically employed, it is necessary that the moving parts should be carefully balanced, the steam passages and ports carefully proportioned, the bearing surfaces ample, and provision be made for a thorough system of lubrication.

Time will not permit us to enter into further details at present, but enough has been said to show that the development of the steam-engine has followed that order which holds not only in the animal and vegetable kingdom, but also in the domain of social science. The law of evolution as applied by Herbert Spencer to social progress is enunciated by him in the following words:— "*Evolution is a change from an indefinite incoherent homogeneity to a definite coherent heterogeneity, through continuous differentiations and integrations.*" This, when translated into every-day language, and applied to the steam-engine, simply means that in its early stages it consisted of few parts or organs, and that each of these performed several distinct functions, that it gradually proceeded with increasing complexity of construction from indefiniteness to definiteness and certainty in the actions of its parts, accompanied by an increase in the number of those parts, but at the same time the whole becoming more compact and more easily managed. The conditions attending its development are:—

1st. That the fuel be efficiently used, and the heat produced efficiently applied to the production of steam.

2nd. That it receive all its heat at the highest, and reject it at the lowest possible temperature.

3rd. That its design be specially adapted to the use for which it is to be employed.

4th. That the best disposition and grouping, and the most advantageous proportions of the cylinders, and the highest piston speed consistent with safety, be adopted.

5th. That the mechanical details of the working parts be suited to their special purposes and correctly proportioned.

These conditions, with the exception of the first and second, are all fairly well attended to in ordinary designs. Enormous quantities of fuel are still wasted by not taking advantage of the known laws of combustion, and while, although the thermodynamic conditions of efficiency are gradually being attended to, it has taken nearly forty years from the time that those conditions were first enunciated to reach the present state of efficiency, and only after an enormous waste of time and money. If any one should take the trouble to calculate what might have been saved if, as the result of a well designed series of experiments, combined with what was then known of the fundamental laws of thermodynamics, engines had been made to work as economically, say 30 years ago, as we know they can be made to work now, he would find that the amount would go a long way towards liquidating the National Debt. In view of the prospect of the comparatively near exhaustion of our coal-fields, the question of economy of fuel is one which affects the very existence of the nation. Even now, such experiments as I have mentioned are much wanted, the question to decide is—"Who is to undertake them?"

APPENDIX.

Catalogue of some of the chief works relating to the Steam-Engine:—

DATE.

1629.—*Branca.* La Machine.

1663.—*Marquis of Worcester's* Century of Inventions. Several other editions.

1695.—*Papin.* Recueil de Pièces.

1702.—*Savary.* The Miner's Friend.

1704.—*De Caus.* New Invention of Water Works. Translated from the French edition of 1657.

1730.—*John Allen.* Narrative of several new Inventions and Experiments, particularly the Navigating a Ship in a Calm.

1737.—*Hull.* Description of a new invented Machine for carrying Vessels or Ships out of or into any harbour, port, or river against wind and tide.

1763.—*Desaguliers's* Course of Experimental Philosophy.

1774.—*Blakey.* Sur les Pumpes à feu.

1780.—*Leupold.* **Theatrum Machinarum Generale.**
1782.—*Belidor.* **Architecture Hydraulique.**
1786.—*Bossut.* Traité Theorique et Experimental d'Hydrodynamique.
1790.—*Prony.* Nouvelle Architecture Hydraulique.
Boulton and *Watt's* Directions for erecting their new invented Steam-Engine.
1793.—*Blakey.* A short Historical account of the Invention, Theory, and Practice of Fire Machinery; or, introduction to the art of making Machines, vulgarly called Steam-Engines.
1797.—*Smeaton's* Reports.
1797.—*Curr's* Coal Viewer and Engine Builder.
1797.—*Walker's* System of Philosophy.
1816.—*Buchanan* on Propelling Vessels by Steam.
1818.—*Dodd* on Steam Packets.
1822.—*Partington.* Historical and Descriptive Account of the Steam-Engine.
1824.—*Stuart's* History of the Steam-Engine.
1824.—*Sadi Carnot.* Réflexions sur la puissance motrice du feu.
1827.—*Farey.* A Treatise on the Steam-Engine: historical, descriptive, and practical.
1836.—*Galloway* (*R.*). History of the Steam-Engine.
1836.—*Pambour.* New Theory of the Steam-Engine.
1839.— ,, Practical Treatise on Locomotive Engines.
1841.—*Scott Russell, J.* Nature, Properties, and Application of Steam.
1841.—*Scott Russell, J.* Treatise on Steam Navigation.
1844.—*Pole, W.* Treatise on the Cornish Engine.
1847.—*Alban.* The High-Pressure Steam-Engine.
1847.—*Craddick.* Chemistry of the Steam-Engine.
1848.—*Woodcroft, B.* A Sketch of the Origin and Progress of Steam Navigation.
1848.—*Renwick.* Treatise on the Steam-Engine.
1849.—*Hodge, (P. R.).* The Expansive Steam-Engine.
1850.—*Tredgold, T.* The Steam-Engine: its progressive and present state of improvement.
1851.—*Woodcroft.* The Pneumatics of Hero of Alexandria. Translation from the Greek.
1851.—*Lardner, Dr.* The Steam-Engine; Steam Navigation; Railways.
1852.—*Bourne.* Treatise on the Screw Propeller.
1854.—*Muirhead, J. P.* Origin and Progress of the Mechanical Inventions of James Watt.
1857.—*Westcott.* Life of John Fitch the inventor of the Steamboat.
1859.—*Rankine, W. J. M.* The Steam-Engine and other Prime Movers. Several later editions have been published.
1860.—*Clark, D. K.* Railway Locomotives.

1860.—*Clark and Colburn.* Recent Practice on the Locomotive Engine.
1861.—*Armengaud, A.* Traité Theorique et Pratique des Moteurs à Vapeur.
1862.—*Hirn, G. A.* Exposition Analytique et Experimentale de la Theorie Mecanique de la Chaleur.
1866.—*Rankine, W. J. M.* Shipbuilding, Theoretical and Practical.
1876.—*Bourne.* Treatise on the Steam-Engine. The first edition was published in 1846.
1876.—*Clausius.* Die Mechanische Wärmetheorie. Translated into French and English.
1876.—*Tideman.* Memorial van de Marine.
1877.—*Zeuner.* Grundzüge der Mechanischen Wärmetheorie. Translated into French.
1878.—*Thurston, R. H.* History of the Growth of the Steam-Engine.
1878.—*Cotterill, J. H.* The Steam-Engine considered as a Heat Engine.
1881.—*Galloway, R. L.* The Steam-Engine and its Inventors.
1832.—*Ledieu, A.* Nouvelle Theorie Elementaire des Machines à Feu.
1882.—*White, W. H.* A Manual of Naval Architecture.
1882.—*Sennett, R.* The Marine Steam-Engine.
1883.—*Seaton, A. E.* A Manual of Marine Engineering.
1885.—*Busley, C.* Die Shiffsmaschine.
1886.—*Bienaymé, A. T. H.* Les Machines Marines.

The following papers may be referred to for a more detailed account of recent progress in marine engines :—

Bramwell.—On the Progress Effected in Economy of Fuel in Steam Navigation. Proc. Inst. Mech. Eng., 1872.
Marshall.—On the Progress and Development of the Marine Engine. Proc. Inst. Mech. Eng., 1881.
Parker.—On the Economy of Compound Engines. Trans. Inst. Nav. Arch., 1882.
Kirk.—Engines of the s.s. *Aberdeen.* Trans. Inst. Nav. Arch., 1882.
Parker.—On the Progress of Marine Engineering. Trans. Inst. Nav. Arch., 1886.
Dyer.—On the Present State of the Theory of the Steam-Engine, and some of its bearings on Current Marine Engineering Practice. Trans. Inst. Eng. Scot., 1885.
Wyllie.—Triple Expansion Engines. Trans. Inst. Mech. Eng., 1886.

II.—*On Abbe's Apochromatic Micro-Objectives and Compensating Eye-pieces, made of the new Optical Glasses in the Works of Dr. Carl Zeiss in Jena, with some general remarks on Object Glasses.* By ADOLF SCHULZE.

[Read before the Society, 17th November, 1886.]

IT is at the request of Dr. M'Kendrick that I come here this evening in order to call your attention to an important advance which has quite recently been made in the construction of microscopical objectives, an advance which is a matter of the greatest possible interest and gratification, not only to the microscopist, but to many others besides; because the means by which this improvement has been attained are equally applicable to the construction of telescopes, photographic lenses, spectroscopes, and, in fact, to the construction of nearly all optical instruments. I refer to the invention of new kinds of optical glasses, which permit, firstly, of the almost complete correction of the spherical aberration of lenses, as far as their curvatures will permit; and, secondly, of the correction of the chromatic aberration by the elimination of the so-called secondary spectrum.

Those of you who have followed the improvements in the construction of the microscope during the last ten years will be aware that they are nearly all due to the genius of Dr. Ernest Abbe, Professor in the University of Jena, now the first living authority on microscopical optics, and who, in the execution of his inventions, is most ably seconded by the eminent optician, Dr. Carl Zeiss. It was Professor Abbe who gave us a few years ago his now famous theory of the formation of the microscopical image by diffraction spectra, a theory which is easily proved by a series of experiments which are among the most interesting and fascinating in the domain of experimental optics; and it was Abbe who introduced lucid mathematical expressions of the relations of aperture, resolving power, and penetration; in fact, it was he who brought light where formerly there had been nothing but confusion and darkness. It was Abbe also who, about seven years ago, invented the objectives for homogeneous immersion; and now we have to thank

him for his Apochromatics, by far the best lenses ever constructed, and which are destined to supersede ultimately all other micro-objectives previously made.

The Micro-objective is the most essential part of the microscope. It is that lens or combination of lenses which is nearest to the object, and forms of it an enlarged, inverted, and reversed image, which is again further enlarged by the ocular or eye-piece. The eye-piece, however, cannot bring out or resolve any more details of the object than the objective has transmitted to it; it can only magnify these details still more. A good Micro-objective is a system of lenses, consisting often of as many as twelve, which are composed of crown and flint glasses, and are ground to certain spherical curves. The following are the *relative qualities of a Micro-objective:*—First of all, its *defining power* or *definition*, which depends upon the more or less perfect correction of the spherical and chromatic aberrations; secondly, the *resolving power*, or the power to separate and make visible close structural details, surface-markings, bands of lines and gratings, and this resolving power is, as Abbe has shown us, dependent upon the aperture of the lens, which is the power to collect and transmit a smaller or larger cone of rays from the object to the eye-piece; thirdly, the *penetrating power* or *focal depth*, which consists of the vertical range through which parts of an object of different planes can be seen at the same time. As the penetrating power decreases inversely with the square of the resolving power, it follows that narrow-angled lenses possess far greater penetration than wide-angled ones, which latter possess very little. The *flatness* is that quality of a lens which admits of the image being seen with the same distinctness in the centre as at the margin of the field, without any readjustment of the focus. The *working distance* has no fixed relation to the focal length, because all compound objectives are stated by their equivalent focal lengths—*i.e.*, by the focal lengths of single lenses possessing the same magnification. Wide-angled lenses have shorter working distances than lenses of narrow angles; the working distance for some of the dry high-power objectives, such as the $\frac{1}{50}$-in., being for instance only ·003 inch.

A good objective should combine all the foregoing qualities in the greatest degree compatible, but for special purposes some of these qualities may have to be sacrificed to others, though the definition should never be sacrificed. As I shall have to speak a good deal of spherical and chromatic aberration, I may as well state

here that the spherical aberration is that optical imperfection of a spherical lens which brings the rays passing through its marginal zone sooner to a focus than the rays passing through its central part, so that the focus, instead of being a point, becomes a short line. The chromatic aberration arises from the unequal refrangibility of the several coloured rays which make up white or uncoloured light, so that they are not all brought to the same focus even by a lens free from spherical aberration. Lenses act like prisms and disperse the light into a spectrum, the violet and blue rays of which fall within the principal focus, whilst the red being the least refrangible rays fall somewhat beyond it.

Since Professor Abbe formulated the expression of *Numerical Aperture*—by which is understood the product of the sine of the semi-aperture of a Micro-objective and the refractive index of the medium in which its front lens is immersed, be that medium either air, water, glycerine, or oil,—the vast superiority of wide-angled immersion lenses over the so-called dry lenses of high powers has been at once demonstrated, opinions formerly differing greatly regarding the respective merits of dry and immersion lenses. No dry front lens can collect image-forming rays from a radiant in balsam, or a similar refractive medium, making a greater angle than about 82 degrees; nor can an immersion lens do so if the radiant is in air or mounted dry, because, according to the law of total reflection, no ray of light can pass from air into crown glass and through it if the angle of incidence is 41 degrees or more, but is reflected out again under the same angle, the sum of the angles of incidence and reflection with the normal being about 82 degrees. This is a principle that is made much use of in microscopical illumination, especially for the illumination of objects on dark ground. The power of a microscope is not, as is popularly supposed, its mere magnifying power, but its power of showing surface markings, structural details, and separating or resolving closely-ruled bands of lines with the best definition possible. This power of showing detail, or the resolving power of an objective, is a direct function of the numerical aperture. The greater the angle, or rather the sine of the angle, of the rays proceeding from the radiant or object into the front lens, and the greater the refractive index of the medium intervening between the anterior lens of the objective and this radiant, the greater is the resolving power,—equal corrections of the spherical and chromatic aberration being assumed. A lens magnifying, say, only one-tenth as many

times as another may be more powerful than it by virtue of the greater numerical aperture which it possesses, and will be capable of showing details which the more highly-magnifying lens of smaller aperture is unable to resolve. The aim in Microscopy is not to magnify and amplify as many times as possible, but to see minute details clearly with as little magnification as practicable; mere magnification being easily obtained at the other end of the tube by high eye-piecing, provided the objective is so well corrected that it does not break down under the strain of deep oculars.

I referred to the Abbe *diffraction theory of the formation of the microscopical image*, the substance of which is simply this that the diffraction images produced by the passage of the rays of light through closely approximated lines or structures have a most important share in the formation of microscopical images, it being formerly assumed that these were solely produced in accordance with the laws of refraction, or in other words that they were mere dioptric images. This, however, is only the case within a certain limit, and both Professors Abbe and Helmholtz have found by theoretical researches that no amount of magnifying power can separate or resolve markings or details which are more than the $\frac{1}{3500}$th of an inch apart, and that these are solely imaged by their diffraction spectra. The objective has therefore not only to transmit the dioptric beam, but it has also to collect the diffraction spectra, and as these diffraction spectra fall the wider apart the closer the lines are which produce them, it becomes evident that an objective must be capable of collecting a sufficient number of these spectra if the object is to be truly imaged. It is further evident that different objects may produce identical microscopical images, and that the same structure may produce different microscopical images if these objects are viewed with lenses of different apertures. I will give you just one illustration of this theory. Suppose you place on the stage of your microscope a grating consisting of fine parallel lines, every alternate line stopping short in a horizontal line drawn through the centre, in other words, two gratings, of which the upper one has only half as many lines per inch as the lower one, and you focus these gratings with a suitable objective. By removing the eye-piece and looking into the tube of the microscope you will perceive at the back lens two rows of spectra, each having a central circle of bright and colourless light the dioptric beams, and the oval spectra with their blue ends directed towards the centre arranged laterally. The upper row contains twice as

many spectra as the lower one, and corresponds with the wide grating; the lower row contains only half as many spectra as the upper one, and corresponds with the narrow grating. By inserting at the back lens of the objective a grate-shaped diaphragm, the bars of which stop out every alternate diffraction spectrum of the line of close-lying spectra, and by replacing the eye-piece, you will find on looking through it that you have altered the appearance of the object, and that those lines which actually stop short in the horizontal diameter of the field appear now as continuous, and that the whole field appears as one grating of close lines. The explanation of this is that you have now two rows containing the same number of identical diffraction spectra which necessarily yield identical pictures in the eye-piece. If, on the other hand, the diffraction spectra are all stopped out, allowing only the two dioptric images to pass, it will be found on looking through the eye-piece that the grating, which must be finer than $\frac{1}{2500}$th inch, has disappeared or become invisible. By manipulating the diffraction spectra and the dioptric beams of more complex structures their appearances may be greatly varied, and no one who has once tried these beautiful experiments can doubt the correctness of Abbe's theory that microscopical structures of greater fineness than the $\frac{1}{2500}$th inch are solely imaged by their diffraction spectra.

As previously stated, the resolving power is a function of the numerical aperture. Mr. J. W. Stephenson has computed a most useful table, which is regularly published on the covers of the *Journal* of the Royal Microscopical Society. This table gives, for 130 different numerical apertures ranging from ·05 to 1·52, the corresponding angular apertures of dry, water, and homogeneous-immersion lenses, and the number of lines per inch which objectives of these numerical apertures can resolve by white and by monochromatic light, as also the number of lines which these lenses will photograph, this latter number being about 30 per cent. in excess of the lines they can resolve by white light. By measuring the aperture of any objective, which is done with an apertometer such as Abbe's, and by referring to Stephenson's tables, one can find at a glance the number of lines this lens is theoretically able to resolve or to photograph, and in our best objectives the actual result falls very little short of the theoretical limit.

The greatest improvements in the construction of Micro-objectives during the last six years, that is to say, since the introduction of

the homogeneous-immersion system, have nearly all tended in the direction of the increase of the numerical aperture, which has been advanced from 1·2 to 1·5 in homogeneous-immersion lenses, and we have thus almost reached the theoretical limit. It is, however, very doubtful whether by going beyond 1·3 or 1·4 with the numerical aperture anything further can be gained; certain it is, on the other hand, that by going beyond these values the working distances of lenses become reduced to impracticably short dimensions, and consequently the range of objects upon which such lenses can be brought to bear is very limited, whilst the difficulties of construction and the expense connected with the production of lenses of extreme apertures become greatly enhanced. The loss of penetrating power, which decreases with the square of the numerical aperture, is also a very serious drawback in lenses of extremely wide apertures. Professor Abbe long ago recognized that by pushing the aperture of objectives beyond its legitimate limit, no adequate advantages could be obtained; and he therefore directed his attention to the attainment of superior definition, or the better corrections of the spherical and chromatic aberrations. Unfortunately, with the means at the command of opticians—viz., with the crown and flint glasses then in use, this was not possible, and new optical media had first to be found before further improvements could be attained. In 1881, Dr. Abbe induced Dr. O. Schott, of Witten in Westphalia, a chemist of great experience in the manufacture of glass, to make for him numerous small quantities of experimentally-produced glasses, and, as these experiments bore germs of promise, Dr. Schott removed in 1882 to Jena, to establish there a melting laboratory in order to repeat his experiments on a larger and more practical scale. More than a thousand different glasses were compounded, and prisms were ground out of them, which were examined by means of the spectroscope and the refractometer, in order to establish the relations of their optical properties to their chemical composition, with the result that a number of new optical vitreous media were obtained which possessed the properties aimed at, viz.:—

(1.) Crown and flint glasses, in which the dispersion for the different regions of the spectrum shows approximately the same ratio, and which admits consequently of the almost complete elimination of the so-called secondary spectrum in achromatic combinations.

(2.) The increase of the number of optical media, in such a way

that with the same refractive index a dispersion, or with the same dispersion a refractive index can be obtained, not, as hitherto, only in combination with flint glass of high dispersive powers, but also with lower dispersion, as in crown glass.

The attention of the Prussian Government having been directed to the researches of Drs. Abbe and Schott, who were enthusiastically and materially assisted by the Messrs. Zeiss, it granted to these gentlemen a subsidy of £3,000 on the most liberal terms possible. A not inconsiderable manufactory has now been established in Jena for the production of glasses for optical and other scientific purposes, under the name of the Glastechnische Laboratorium, Schott und Genossen, which has issued an interesting catalogue compiled on a strictly scientific basis. This catalogue contains a list of 44 glasses, of which 19 are quite new. The list gives the specific gravity, the refractive indices (which vary from 1·5151 to 1·9626, the latter for the heaviest silicate flint glass), and the mean dispersion, which varies from 0·00737 to 0·04882. There is also a price list of discs for telescope objectives up to 20 inches diameter. These new vitreous media contain many elements, some of them as many as 14, but the chief constituents seem to be silicates, borates, and phosphates.

Mr. Zeiss is the first optician who has made Micro-objectives of these new optical glasses, and these lenses have been beautifully made according to the formulæ and data given to him by Professor Abbe. In these lenses Zeiss has been able to overcome the greatest defects of objectives, the optical glasses hitherto available forming an insurmountable barrier to further improvements. In consequence, namely, of the great disproportion of the dispersion of the various colours of the spectrum, our best so-called achromatic lenses have up to now been only corrected for two colours of the spectrum, and the unavoidable residue of unachromatism—the so-called secondary spectrum—was always more or less perceptible. In the new lenses it has been possible to bring three colours to one focus. The optical glasses formerly used in the construction of Micro-objectives likewise did not permit of the correction of the spherical aberration for more than one colour. Objectives, although fairly-well corrected for the middle of the spectrum, showed, nevertheless, a spherical under-correction for the red and a spherical over-correction for the blue and violet rays, which imperfection appeared as a more or less great inequality of the achromatic correction between the central portion and the peripheral zones

of an objective. These defects caused an imperfect combination of the image-forming rays, and the result was that objectives, especially those of large apertures, did not stand high eye-piecing, because the defects of spherical and chromatic aberration became more apparent with them than with the lower magnifying ones. In the new lenses the spherical aberration has been completely corrected for two different colours of the spectrum, and therefore practically for all.

Dr. Abbe has called his new lenses *Apochromatics* or *Apochromatic Objectives*, owing to their superior spherical and chromatic corrections, which represent a higher order of achromatism than that hitherto attained.

The *practical advantages* which these Apochromatics possess over other Micro-objectives are the following:—

(1.) Owing to their superior corrections, the full value of their large apertures becomes now only apparent. Indeed, the images formed by the new dry and water-immersion lenses are scarcely distinguishable from those formed respectively by the old water and homogeneous-immersion lenses of even perceptibly larger aperture.

(2.) The largest magnifications for a certain aperture may be obtained by high eye-piecing and by objectives of relatively long foci, thus obviating the necessity for objectives of extreme short focal lengths. The apertures of the old lenses are estimated to stand profitably eye-pieces magnifying from four to six diameters, whilst those of the apochromatic objectives, even those of the largest aperture, will stand an amplification of at least 12 to 15 diameters, and hence a very much larger range of useful magnification can be obtained with them.

(3.) By the correction of the secondary spectrum, and the (for all practical purposes) perfect correction of the spherical aberration, the visual and the actinic foci of these objectives coincide, rendering them especially suitable for photo-micrography.

(4.) The increased spherical and achromatic corrections of the new objectives produce a much larger concentration of light in the images produced by them.

(5.) The objects viewed by them appear in their natural colours.

Special eye-pieces, however, are required, in order to utilize to

their fullest extent the capabilities of the new lenses, and Dr. Zeiss has constructed suitable eye-pieces, which he designates Compensating Oculars. The front lenses of objectives of short focal lengths are single crown glass lenses, which are therefore unachromatic. All objectives of wide aperture in which the front lens of the system cannot be achromatized itself, although well corrected for their chromatic aberrations in their centres, show yet a considerable difference of magnification for the different colours in the marginal zone, which appears as coloured outlines. The picture produced by the blue and violet rays is larger than the one produced by the yellow rays. The so-called compensating eye-pieces are designed with a view to correct this residue of peripheral aberration, or to balance or compensate these chromatic differences of magnification. But to make these compensating oculars available not only for the objectives of wide aperture, but also for those of moderate aperture, or for the low powers—these latter had to be so constructed that their marginal zone should possess practically the same aberrations as the objectives of great aperture. The compensating eye-pieces may also be used with wide-angled objectives of older construction.

The classification of the compensating oculars has been carried out on Abbe's plan, and they are designated by their magnifying power at a tube-length of 250 mm., which carries at its other end the apochromatic objective. Thus, instead of naming the eye-pieces A, B, C, D, etc., or 1, 2, 3, 4, &c., we have—

Eye-pieces 1, 2, 4, 8, 12, 18, 27—

magnifying 1, 2, 4, 8, 12, 18, and 27 times respectively, under the conditions stated. Both the focal length and number or magnifying power are engraved on each eye-piece, and the magnification of the microscope can therefore be easily calculated by simply *multiplying* the number of the ocular with the initial magnifying power of the objective at the conventional tube-length of about 10 inches, or 250 mm. Thus, for instance, an objective of 2·5 mm. focus magnifies 250 divided by 2·5, or 100 diameters, and in combination with No. 18 eye-piece, 1800 diameters.

The eye-pieces are made in two series—one for the Continental stand, having a tube of 160 mm., and the other for the English stand, having a tube of 250 mm. length; but both series are so arranged that they give the same magnifying powers. The settings of these oculars are so constructed that the lower foci of all those

belonging to one series are lying in the same plane when inserted in the body of the microscope, so that no alteration of the focal adjustment is required when interchanging them.

The compensating eye-pieces are of three kinds, viz.:—

(1.) *Search oculars or finders* of great focal length. No. 1 for the Continental stand does not magnify the image projected by the objective at all, whilst No. 2, which is made both for the Continental and English stands, magnifies this image only two diameters. I have found these oculars a very great boon when searching for a certain object on a slide, as they can be instantly exchanged for another eye-piece, and that without requiring a re-adjustment of focus, whilst the double nose-piece—which generally carries besides a high-power system, also a low-power one as a finder—is cumbersome and prejudicial to the centricity of the optical system, and necessitates invariably a readjustment of the focus. A great saving of time, labour, and inconvenience can thus be effected by these search oculars, especially when using immersion lenses.

(2.) *The ordinary working oculars*, magnifying 4, 8, 12, 18, and 27 diameters, respectively; their focal lengths varying from 45 to 10 mm. for the Continental tube, and from 67 to 10 mm. on the English 10-inch tube. These working oculars have all relatively large eye-lenses, whose foci lie so much above their upper surfaces that the usual inconvenience of working with Huyghenian eye-pieces of short foci is not felt, and the camera lucida can also be used with all of them except with No. 27.

(3.) *Oculars for projection*, magnifying two and four diameters for a tube of 160 mm., and three and six diameters for a tube of 250 mm., or 10 inches long, respectively. These oculars have two diaphragms each to reduce the effective apertures of the high-power lenses, should such appear desirable. They are constructed for photo-micrography and for the lantern microscope, and yield an evenly-illuminated flat field and a well-defined image at any screen distance; they can also be used advantageously with ordinary high-power achromatic objectives.

The apochromatic objectives made in Dr. Zeiss' establishment are comparatively few, because, owing to the great range of magnifications they are able to bear, fewer objectives than formerly are now required to form a complete and effective working series.

The following is a list of the new Apochromatics:—

Num. Aper.		Equivalent focal length in mm.		Theoretical limit of resolving power of lines per inch.	
				For white light. Line E.	On the photographic plate. Near line K.
Dry system.	N.A. 0.30	24.0	1	25,963	35,699
	0.30	16.0	1		
	0.65	12.0	1	57,566	76,190
	0.65	8.0	1		
	0.85	4.0	1	96,309	130,645
	0.85	4.0	1		
Water immersion.	1.25	2.0		130,313	158,745
Homog.	1.30	3.0	1	135,135	166,667
	1.30	2.0	1		
	1.40	3.0	1	138,574	177,778
	1.40	2.0	1		

These are manufactured only for the English trade.

With this series nearly up to 135,000 lines per inch can be made visible, and up to 177,778 lines per inch can be photographed, whilst lenses are similar that the [illegible] part of an inch can be seen with the highest power, for the resolution of such lines must not be confounded with seeing minute small objects. The homogeneous-immersion lenses are constructed without screw collars for the adjustment for covering glasses of different thicknesses—the invention of Andrew Ross,—and they have to be used with [illegible] value when in use of the refractive index 1.51.5. In spite of their high apertures they will work through covers nearly [illegible] inch thick. These oil-immersion lenses are generally called homogeneous-immersion lenses, because the immersion fluids with which they are to be used, and as mentioned before when in use some other medium, oils and solutions of certain salts, have the same refractive index as crown glass, of which the front lens of the objective and the covering glass are made, and all of which have, therefore, optically a homogeneous effect.

The apertures of Micro-objectives are measured at their back lenses, because the same angular aperture of a dry and an immersion lens is quite a different thing, for the angle of an immersion lens is equivalent to a larger cone of rays in air which has been contracted by the refractive power of the immersion fluid into the same angle as that of the dry lens. The reflection and consequent great loss of light on the plane surface of a dry lens is another point constituting a drawback to high dry powers. This loss of light by reflection does not occur in immersion lenses. The greatest angular aperture which a dry front lens can possess is, of course, 180 degrees, and as the refractive index of air and the sine of 90 degrees are 1, it follows that the numerical aperture for such a lens is 1, which corresponds to an angle of 90 degrees for a water-immersion lens, and to one of 82 degrees for a homogeneous-immersion lens. The angular aperture of a water-immersion lens of 180 degrees is equivalent to a numerical aperture of 1·33, and the angular aperture of a homogeneous-immersion lens of 180 degrees is equivalent to a numerical aperture of 1·52. From these values of numerical aperture it is evident that if the greatest amount of resolving power which a dry lens can possess be stated as 1, then the greatest resolving powers of water- and homogeneous-immersion lenses are 1·33 and 1·52 respectively.

The following diametrical magnifications may be obtained with the apochromatic objectives and compensation oculars:—

Equivalent Focal Length in mm.	Search Oculars.		Working Oculars.				
	1	2	4	8	12	18	27
24·0	...	21	42	83	125	187	281
16·0	15·5	31	62	125	187	281	...
12·0	...	42	83	167	250	375	562
8·0	31	62	125	250	375	562	...
6·0	...	83	167	333	500	750	1125
4·0	62	125	250	500	750	1125	...
3·0	83	167	333	667	1000	1500	...
2·5	100	200	400	800	1200	1800	...
2·0	125	250	500	1000	1500	2250	...

Dr. Zeiss has sent me four of these Apochromatics for inspection, viz.:—those of 16, 4, 2·5, and 2 mm. focus, which I have carefully tested and compared with the older forms, and I find that they surpass by far any objective I have previously examined. Their definition is exquisite, their resolving power is very great, and the pictures yielded by them are most brilliant and free from colour; they possess, further, a very notable increase of illuminating power and give great flatness of field I have also tested these Apochromatics for their photographic capacity, and as a proof of their perfect suitability for this purpose I have brought a few negatives of diatoms and other objects, among them one of *Amphipleura pellucida*, which shows the striæ quite distinctly resolved. The *Amphipleura pellucida* is a microscopic shell, $\frac{1}{2125}$-inch long and $\frac{1}{5500}$-inch broad, and bears on its surface cross-marking of the utmost regularity counting at the rate of about 100,000 per inch. To see those lines on a photograph plainly with the unarmed eye, the diatom requires to be magnified nearly 2,500 diameters, or about 6,250,000 times superficially. All these negatives were taken by ordinary lamp-light.

Thanks chiefly to the labours of Professor Abbe, the microscope is to-day perhaps the most perfect optical instrument which we possess, for it appears, both from theoretical and practical considerations, that with it we have as good as reached the limit of microscopical vision, and that no further important improvement is possible, until suitable media of far greater refractive power than any we possess at the present time have been discovered and placed at the service of the optician.

III.—*Preliminary Experiments on the Effects of Percussion in Changing the Magnetic Moments of Steel Magnets.*

By WILLIAM BROWN ("Thomson" Experimental Scholar), Physical Laboratory, University of Glasgow.

[Read before the Mathematical and Physical Section of the Society, 30th November, 1886.]

THE experiments described in this paper were made in the Physical Laboratory of Glasgow University. They were first suggested by some casual observations made while I was assisting Mr. T. Gray during his recent determination of the horizontal intensity of the earth's magnetic force, and I am greatly indebted to him for many hints and much valuable advice during the progress of the experiments.

This paper is merely preliminary to what may ultimately prove to be a somewhat extended series of observations on the same subject if time and opportunity offer.

The effects of percussion in changing the magnetic moments of steel magnets have not (so far as I know) been made the subject of special observation. The results hitherto published have, for the most part, formed less important sections of other investigations.

In 1878, Mr. T. Gray* published a very accurate series of investigations on magnetic moments in absolute measure. One of the objects of his investigation was to obtain information as to the permanence or non-permanence of magnetism in steel bars when left *undisturbed* for a length of time. On page 328 of the same paper, however, he gives a short series of observations on the direct effects of percussion, which, as far as they go, agree with my own results.

*"Experimental determination of Magnetic Moments in absolute measure." *Phil. Mag.*, November, 1878, pp. 321-331.

There has been published quite recently an excellent series of papers on the "Electrical and Magnetic Properties of the Iron Carburets," by C. Barus and V. Strouhal, of the U.S.A. Geological Survey.*

In one of these papers the authors treat incidentally of magnetic retentiveness, but more with respect to the effects of annealing than of direct percussion. Annealing appears to play an important part in the ultimate retentive power of magnets, and on the constancy of their magnetic moments. My own experiments on annealed magnets are not yet complete enough to be put into presentable form, and with two exceptions the results given are for magnets tempered glass-hard. Regarding the effects of annealing generally, the results of Barus, Strouhal, and Gray appear to agree on the whole.

On pages 326-7 of Gray's paper it appears that annealing increased the magnetic moment. This is the result stated generally in the text; but a marginal note and curve in the copy in my possession show that the magnetic moment did not increase continuously as the annealing went on, but increased at first, then diminished, then again increased—thus passing a maximum when the annealing temperature was about 150° C., and a minimum when the temperature was about 230° C.

Another set of results given in this paper is a series of magnetic moments for bars of the same steel tempered in oil, the temperature of which was varied so that the bars should be suddenly cooled only to the same temperature as that to which in the first set they were heated in the annealing process. The results in this second set show precisely the same characteristics as those of the first set, only that the maximum and minimum points are much more pronounced.

The curves given by Mr. Gray indicate a much more interesting peculiarity than those given in the paper of Barus and Strouhal, already referred to, inasmuch as they show that the minimum point may be preceded by a maximum, the effects of annealing depending greatly on the kind of steel used. The steel used by Gray was almost a pure charcoal steel, whereas that used by Barus and Strouhal was of the kind known as "English silver steel"—that is to say, of a kind similar to that which I have been experimenting on.

---

* Bulletin No. 14, 1885, Department of the Interior.

Mr. Gray in his paper refers very briefly to some experiments on other steels, chiefly, it would appear, for the purpose of showing how very different results may be expected from different specimens. In one set, which took an average magnetic moment of about 50 per gramme, the magnetic moment was slightly diminished by hardening; whilst in another set the direct opposite was arrived at in a very marked manner, showing how very much the effect of annealing depends on metallic impurities in the steel. The diminution of the magnetic moment of one of his specimens by annealing, Mr. Gray tells me, he believes to be due to the known presence of manganese in it.

The behaviour, however, of alloys in the annealing and magnetic retentiveness of steel magnets needs further elucidation before anything very definite can be said on the subject. The effects of small quantities of tungsten in increasing the magnetic retentiveness of steel are well known; whereas the recent experiments of Hopkinson, Bottomley, and others tend to show that a very moderate quantity of manganese in steel almost totally destroys not only the magnetic retentiveness but even the magnetic susceptibility.

With respect to the "silver steel," of which my magnets are made, I am in doubt as to whether it really contains silver. Some well-known steelmakers say it is only a trade name.

In preparing the magnets, great care was taken to have them made straight, and the ends made as accurately as possible at right angles to their length. In tempering them they were put into an iron tube having one end closed, and the whole put into a brisk coal fire, and left there till they attained a bright red heat. The tube, with the magnets inside, was then taken out, and, with the open end temporarily closed by a glass plate, was held vertically above a vessel of water at a temperature of 15° C., and about 20 inches deep. The glass cover was then quickly withdrawn, and the magnets were allowed to drop perpendicularly into the water, thus making them all glass-hard.

A greater number of magnets than were actually required were treated in this manner, and only the straightest and most uniform in temper were chosen for the experiments. This was the method employed in tempering all the glass-hard magnets, and was adopted mainly in order to obtain an indication of what kind of results were to be expected. In subsequent experiments, however, a method somewhat similar to that used by Gray and Barus

will be employed. The two exceptions to glass-hardness already referred to—those tempered blue and yellow—were first tempered glass-hard along with the others; they were then laid on the top of a hot metallic plate, where they were allowed to remain till they exhibited the oxide tints characteristic of those tempers.

The magnets were all magnetised to saturation by placing them between the poles of a large Ruhmkorff electro-magnet, excited by a dynamo giving a potential of between 80 and 90 volts. During the process of magnetising, the magnets were reversed several times between the poles of the electro-magnet, and then finally magnetised. This was done in every case for the first set of six magnets, when they were re-magnetised after a series of observations.

In order to obtain the deflections for calculating the magnetic moments, the apparatus used consisted of a lamp and scale, a magnetometer, and a cradle for holding the magnets. The magnetometer was of the ordinary Bottomley type, consisting of a small circular mirror, with two short magnetic needles attached to the back of it, and suspended by a single torsionless silk fibre —the whole being enclosed in a slot cut in a pyramidal block of wood, and the slot covered by a plate of thin glass. On the base of this pyramid were fixed three conical feet, which fitted accurately into the conical hole, groove, and plane arrangement of Sir William Thomson. The hole and groove were cut out of a piece of thick plate glass, which was firmly fixed to the table in a position where the horizontal component of the Earth's magnetic force was known. When the magnetometer was put in position the mirror and the attached needles, of course, placed themselves in the magnetic meridian.

Immediately to the west of the magnetometer, at a distance of 40 cms., was placed a cradle for holding the magnets during the deflection observations. The base of this cradle was made on the same geometrical principle as that of the magnetometer, and was so arranged that the magnet could be reversed relatively to the magnetometer, without touching the magnet by hand. This cradle, I may say, was made and used by Mr. Gray in his recent determination of the earth's horizontal magnetic force; the whole arrangement is fully described and illustrated by a drawing in his paper.*

* Measurement of the Intensity of the Horizontal Component of the Earth's Magnetic Field. *Phil. Mag.*, Dec., 1885, pp. 484-497.

To the east of the magnetometer, at a distance of 129 cms., was a glass scale divided to millimetres, and having a lamp placed immediately behind it. The deflection of the spot of light from the lamp when reflected by the mirror of the magnetometer upon the scale could be read to $\frac{1}{10}$ of a millimetre, by means of the shadow cast by a fine wire stretched across the orifice in the side of the copper funnel of the lamp.

The magnet and magnetometer being placed in position, the magnetic moment of the magnet, M, is given by the following equation:—

$$M = \frac{H \tan \theta \, (r^2 - l^2)^2}{2r}$$

where r = The distance of the centre of the magnet from the centre of the magnetometer needle.

l = Half the distance between the poles of the deflecting magnet (in these experiments, taken as half the actual length of the magnet).

H = The horizontal component of the earth's magnetic force=·153, c.g.s. units.

θ = The deflection in degrees of the magnetometer needle.

In order to test the constancy of the magnetic field during the experiments, the deflections given by a standard magnet were occasionally taken.

The method employed to obtain the effects of percussion with the least possible amount of handling of the magnets, was as follows:—A series of glass tubes, wide enough inside to allow the magnets to fall through them freely, were fixed on a long narrow board by means of brass clamps, which were just loose enough to allow the tubes to slip easily through them. This was for the purpose of raising the tube vertically in order to take the magnet out after falling through it. A thick shelf was firmly fixed at one end of this board, and a thick plate of glass fastened to it. The magnets were held in the hand and allowed to fall vertically through the tube upon the glass plate at the bottom, and always with the true north end of the magnet downwards.

A few trial experiments were made in letting the magnets fall

through a height of a half metre and one metre, respectively; but to give uniformity in the results the 1·5 metre height was adopted throughout.

The plan of experimenting was as follows:—The magnets were magnetised and laid aside undisturbed for the periods of time specified in Table I. One of them was then taken, and the deflection for calculating its magnetic moment was observed. It was then allowed to fall once through the height of 1·5 metres, and the deflection again taken. It was then let fall three times in succession through the same height, and the deflection again taken. Each magnet in turn was put through the same series of operations.

The percentage loss in the magnetic moment due to the one fall, and that due to the three falls, and, finally, that due to the whole four falls, were all calculated, and are shown for the 14 glass-hard magnets in Table II.

In Table I., the percentage loss due to the four falls alone is given. The magnets specified in Table II. had been lying aside for a period of six months after being magnetised, and before they were experimented on.

TABLE I.

Number of Magnet.	Temper of Magnet.	Length and Diameter of Magnet in Centimetres.	Ratio of Length to Diameter.	Weight of Magnet in Grammes.	Magnetic Moment per Gramme.	Percentage loss of Magnetism due to Percussion after lying aside for different periods of time before being experimented on.				
						3 Months.	1 Month.	44 Hours.	20 Hours.	1 Hour.
1	Glass-hard.	10 × ·3	33	5·200	41	0·8	1·04	1·94	2·0	1·98
2	,,	10 × ·2	50	2·084	45	0·0	1·00	1·48	3·2	2·96
3	Yellow.	10 × ·3	33	5·195	44	6·2	5·4	4·8	6·1	6·03
4	,,	10 × .3	50	2·087	46	4·0	2·6	3·76	3·5	4·0
5	Blue.	10 × ·3	33	5·240	54	7·5	11·8	9·71	10·8	11·8
6	,,	10 × ·2	50	3·095	71	8·7	7·5	8·18	8·2	8·2

TABLE II.

The Magnets in this Table were all tempered glass-hard.

No. of Mag.	Length and Diam. of Magnet in Cms.	Ratio of Length to Diam.	Weight of Mag. in Grams.	Mag. Mom. per Gramme.	Percentage Loss of Magnetism due to Percussion after falling the Number of Times specified.		
					1 Time.	3 Times.	4 Times.
1	15 × ·25	60	5·73	56	·67	0	·67
2	15 × ·25	60	5·66	55	·65	0	·65
3	10 × ·3	33	5·25	40	·46	0	·46
4	6 × ·3	20	3·08	36	1·1	·73	1·83
5	3·2 × ·3	10	1·66	27	·7	·7	1·4
6	10 × ·2	50	2·82	43	·43	·11	·54
7	7 × ·2	35	1·97	39	2·1	0	2·1
8	10 × ·15	70	1·39	65	1·05	0	1·05
9	7 × ·15	47	0·98	57	1·2	1·2	2·4
10	10 × ·1	100	0·56	66	0	1·8	1·7
11	7 × ·1	70	0·39	64	0	0	0

By inspection of Table I., we see that in the case of the two glass-hard magnets the percentage loss diminishes the longer they are left undisturbed before they are subjected to percussion; it would also appear that the smaller the dimension ratio the greater is the loss.

The other four magnets, so far as the experiments go, appear to show that the greater the amount of annealing the greater is the loss; the observations, however, have not been sufficiently extended to allow any detailed deductions to be made, and the effects of annealing will form one of the chief parts of subsequent investigations.

From Table II., it will be seen that the greater part of the magnetism has been shaken out by the first fall; this holds throughout, except in the case of magnet No. 10. I am inclined to think this is due to an error in placing the magnet in position; in this case, also, the percentage loss was calculated from a diminished deflection of one scale division only.

IV.—*On a New Tentaculiferous Protozoon and other Infusoria, with Notes on Reproduction and the Function of the Contractile Vesicle.* By WILLIAM MILNE, M.A., B.Sc., F.R.S.E.

[Read before the Society, 15th December, 1886.]

STYLOSTOMA. Nov. gen.

Animalcules solitary, loricate, elongate, attached posteriorly by a soft pedicle. From the anterior end of the body arms extend, each giving rise to a bundle of suctorial tentacles with capitate ends.

STYLOSTOMA FORRESTII. Nov. sp.

(Figs. 1-5.)

Body elongate, somewhat pear-shaped in outline, with a high shoulder; enclosed in a thin membranous sheath, and attached by a short membranous pedicle. The body substance is highly granular, and contains a nucleus and nucleolus. From the anterior indentation spring three arms, transparent, and bearing at their ends numerous suctorial capitate tentacles. These tentacles can be extended sometimes to nearly one-third the length of the body.

The vermiform zooids are very elongate, and attached separately by their own pedicles. Length of body 1-150 inch, arms 1-1200 inch.

Habitat. Marine, attached to a particular form of Cyclops not identified.

It has been thought necessary to institute a new genus to contain this form, as there is no other known in which the suctorial tentacles do not spring directly from the body. It differs from those which have arm processes, as these latter never have separate capitate tentacles. It may be said to connect the two above divisions, and would seem to lie somewhere between Acineta Jolyi and Ophryodendron.

I have much pleasure in naming this species after Rev. Mr. Forrest, Lonmay, to whom I am much indebted for help in this direction.

This animalcule was found in sea water attached to Cyclops, and

always to the same anterior segment. There were as many as six adults and three vermiform zooids on some of the specimens. I have never been able to meet with it a second time, though I have taken water from the same place many times. Any lengthened examination of the same examples was rendered impossible on account of the difficulty of keeping the commensals alive and still. The body is packed full of brownish granules, and accordingly is very opaque. The contractile vesicle was not observed on this account, but the elongated nucleus with a nucleolus was seen. Its food consists of soft-bodied Infusoria, which are caught by means of the tentacles. The tentacles bore into the prey, the fluid contents of which are soon seen streaming down the arms of the Stylostoma into its body. The victim is very soon nothing but a shrivelled skin. The course of the food down the transparent arms is very well seen.

The tentacles can be extended to a great length, and contract in a spiral manner, showing a central muscular fibre which is continued down the arm. These fibres were brought well into view by treatment with Biedermann's fluid—modified for the salt water,—when the arm showed a bundle of fibrillæ (Fig. 5), and spasmodic twitches were seen to take place twelve minutes after death, thus showing the muscular nature of these fibres.

In some examples the nucleus was seen very large and of a very fine brownish granular composition, much like the ovary as often seen in *Philodina citrina*. The male element in both the above Rotifer and Infusorian is unknown, but in the latter it probably is the nucleolus which was observed on one or two occasions broken up into fragments. One or more of these entering the nucleus or ovary would fertilize it. At any rate, the anterior of the ovary (Fig. 2) was seen constricting off and becoming an embryo —not very distinctly, on account of the granular composition of animalcule. The specimen could not be preserved till the embryo escaped.

Vermiform zooids (Figs. 3-4) were often found along with the adults, never attached to them, however, but always on a pedicle of their own exactly like that of the adult. They have also a similar long nucleus and attached nucleolus. These zooids are very elongated and attenuated at both ends. The anterior end bears several short and very fine cilia or setæ. The zooids I consider to be immature and midway between the ciliated embryo and the adult arm-bearing form.

I have not recognised a free embryo, nor have I seen a zooid before it took the elongated form, so that I can adduce no proof that the former develops into the latter. Perhaps the setæ on anterior end of the zooid are the remnant of the cilia of embryo.

There can be no doubt, however, I think, about the zooid being an immature stage, and that it develops into the tentacular form, for one such (Fig. 4) was seen with tentacles just showing out of the breast, as it were. The vermiform zooid stage does not seem to have been noticed hitherto with any of the Infusoria bearing capitate tentacles.

STROMBIDINOPSIS PROBOSCIDIFER. Nov. sp.

(Figs. 6-8.)

Body globose, truncate, surface with deep longitudinal grooves widely apart; not changeable in form, cuticle soft and elastic, covered with short, rather stubbly-looking cilia. There are none of these cilia or grooves on the truncate face; but slightly inwards there is borne a ring of long, very flexible tentacle-like cilia longer than the body, membranellate, and finely feathered with minute cilia all round their whole length. Inside this ring is a membranous collar, not of great height, and inside this again is a soft, elastic, retractile proboscidiform protuberance, the blunt point of which can be protruded higher than the collar, or drawn back into the body entirely below the collar. The point rises nearer one side than the other, and round it there is a spiral fossa, which ends in a slit—the mouth—into the body, with a vibratile membrane or broad cilium. The contractile vesicle is slightly further back than the centre. The nucleus, difficult to distinguish, as the body is always full of large refringent particles, is elongate, and placed transversely near the proboscis.

Reproduction is by means of internal gemmation.

Size, about $\frac{1}{700}$ inch.

Hab. Marine.

This animalcule in general appearance is liker an Arachnidium, but cannot be placed in that genus on account of its body having a covering of cilia. It does not agree, however, very well with the diagnosis of Strombidinopsis as given by Saville Kent.

Its oral appendages bring it nearest to Codonella; but then the latter is loricate, and wants the proboscis, the presence of which in the former allies it again with Didinium. The proboscis, however, is not perforated at its extremity, as in Didinium. The

peculiar oral, tentaculiform cilia would seem to be a step in advance of the membrane of Lankester's Torquatella. This thin membrane, splitting along the frills—the thin edge of each shredding inwards and downwards at very close intervals—would give the fine ciliate feathering of the tentacles of *S. proboscidifer*. That the tentacles had some such origin would seem to be shown by what was observed on one occasion—which might be likened to a reversion or "sport" in the case of a flower—a bar lay on the shoulder (Fig. 7, *a*), probably derived from the nucleus, and sprouting from this, fin-like, were two exceedingly fine, broad, laminate wings, probably one at first, the outer edges of which were finely and deeply serrated.

When at rest (Fig. 6), the cilia are coiled spirally in a very pretty manner, standing up to a certain height and then each falling outwards in a graceful curve. Seen sideways, there is an appearance of a central transparent funnel enclosed by cilia up to where they fall over, but this seems to be an optical illusion from the spiral manner of coiling and the fine cilia inside. Seen from above, and focussing down to near the collar, an appearance is got somewhat like the ventral aspect of a Trichodina, the diatom-like markings (Fig. 8) being got by the fine cilia. The intercrossing of these a little further up the funnel produces a gauzy, lace-like effect. Focussing a little deeper, the eccentric slit mouth is seen, with its vibratile appendage.

The long cilia are pressed to the glass or foreign object about one-third from their roots, and the rest are thrown out along the glass, the points quivering in a tongue-like manner. When about to move, the tentacles begin to quiver and fall out in a graceful shower. It proceeds in an ambulatory manner, each tentacle whirling independently with perhaps two or three curves on it, and pressing against the glass. At these times it has a very spider-like aspect. It crawls over and round about objects in this way, and small particles are entangled in the feathered tentacles and gradually whirled inwards by the finer cilia towards the mouth. This ambulatory is not the only motion, however, for gathering the tentacles forward, it shoots straight ahead at a great velocity with a slight oscillation, cilia foremost. Occasionally it may be seen remaining in one position, oscillating vigorously.

It is a great feeder, scarcely one being seen which was not packed full of diatomaceæ and all kinds of particles. The food is thrown into the central vortex as described, and there whirls round

DESCRIPTION OF PLATE.

Fig. 1-5.—*Stylostoma Forrestii.*

,, 2.—Same, with part of ovary *(a)* budding off.

,, 3.—Vermiform zooid stage.

,, 4.—Same with tentacles beginning to show.

,, 5.—Arm treated with Biedermann's fluid, showing muscular fibres.

Fig. 6-8.—*Strombidinopsis proboscidifer.*

,, 6.—(*a*) Proboscis just showing above collar; (*b*) internal gemmule.

,, 7.—(*b*) Internal gemmule escaping; (*a*) membranous outgrowth.

,, 8.—Perpendicular view of oral fossa.

Fig. 9.—*Oxytricha tricornis.*

Fig. 10-11.—*Ophrydium sessile.*

,, 11.—Contractile vesicle and part of tube.

Fig. 12-14.—*Amphisia multiseta.*

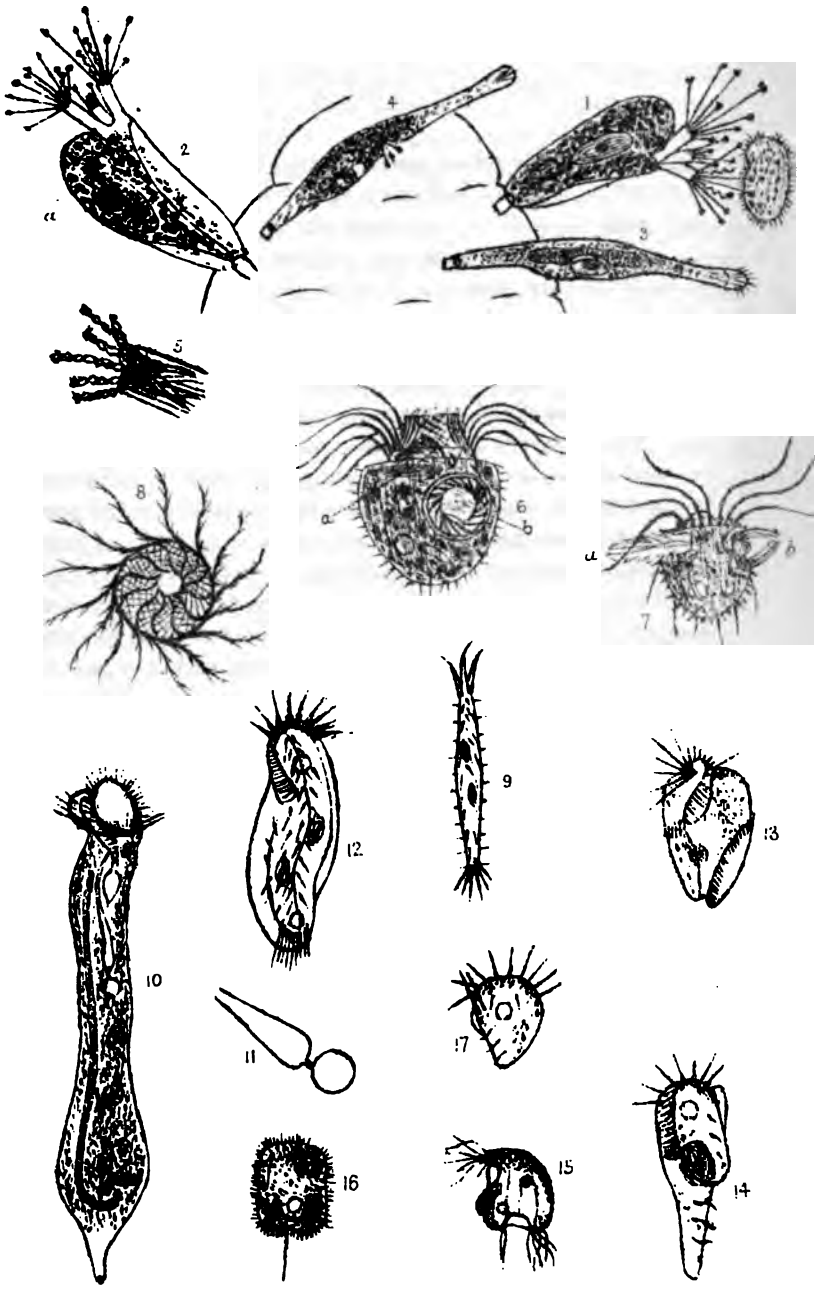
,, 12.—Dorsal view, indurated variety.

,, 13.—*Strombidium viride*, ventral view.

,, 14.—Developmental form of *A. Multiseta.*

Fig. 15-16.—Supposed immature species.

Fig. 17.—Developmental form of colourless variety of *Amphisia multiseta.*



W.M. Del.

V.—*On the Manners and Customs of some of the Tribes of New Guinea.* By the Rev. James Chalmers, of New Guinea.

[Read to the Society, 10th November, 1886.]

In my present mode of living, having no settled abode, simply a wanderer over this land, I have not had the time necessary to prepare a paper worthy of this occasion. It took me some time to decide on a definite subject, and although now I shall go over much ground, yet the most of my time will be occupied with a tribe of sorcerers, known as the Koitapu tribe, and with individual sorcerers.

You have heard of the Motu tribe, who occupy the coast extending from Redscar Bay in the west to Roundhead on the east; and with that tribe the Koitapuans are closely allied. At either end of a Motu village, the Koitapu natives will be found—having left the interior, and come to live under the care of the Motuans. Although the houses are built together, the people speak two distinct dialects; the children seldom meet to play, and as seldom understand one another. Of late years, since the introduction of schools, the Motu dialect is prevailing, and we may hope that in a short time the Koitapuan will disappear.

As a tribe, the Motuans have few traditions, and very little mythology, although a very superstitious people. One night, sitting with a number of old men, they told me that, with the Koiari and Koitapu tribe, they came from two ancestors named Kirimaikuku and Kirimaikape, who came from the earth with one female dog, which they took unto themselves. A son was born, then a daughter, and again a son, followed by a daughter. The first two grew up and married, and their children numbered fourteen. Two went far back inland, and became the progenitors of the Koiari tribe; two went in from the coast by the banks of the Laroge, and from them descended the Koitapu tribe; the others all went to Elema, where they were increased.

Long after, a quarrel occurred in Elema—an elder brother desired his younger one to procure him some sago, but the younger, intent on making a bow, turned a deaf ear to the request. Again and again was the request made, but with the same result. Other members of the family, knowing the elder brother's request, went and procured the sago, but would on no

account let the younger brother have any, and threatened death to any who should give to him even a grain. The difficulty increased, and the younger brother, who had a large following, decided to leave, which he accordingly did, and arrived at Taurama (Pyramid Point), where they remained, increasing in numbers and strength, and finally came to Hamabada (Port-Moresby), where they now live. They speak of themselves as "sea natives," and the Koitapuans as "the land natives." When leaving Elema, the spirit said—"Go, but never forget me; in feast and in dance I will be with you, and the sound of your drums will be heard by me, when I shall indeed bless you."

They found the Koitapu tribe a very powerful one indeed, with chiefs innumerable, who not only killed their enemies by fighting, but also by "meamea" (prayer). Before long they found to their cost that they, too, were under the spell of the Koitapu tribe. Long droughts came, which only these sorcerers could stop, and to get them to do so meant giving pigs, stone adzes, spears, sago, tocas (armlets), and pearl shell; and often these were given with no good results whatever. Something was wrong, and again presents would be given.

These Koitapuans held also the spirits of life and death, and to keep friends with them was the constant aim of the Motu tribe, These spirits travelled in darkness, and would thrust a sharp-pointed instrument between the flooring, touch a sleeper, and he or she would surely sicken and die, the latter certainly if the sorcerer was not called in and well paid. Many prefer sleeping in the open air, and on the ground, so frightened are they of these pests.

The one uncompromising enemy of the Koitapu tribe is Hula, of Hood Point. When these natives go down to the west to fish, and are unsuccessful, they at once say, "Koitapu at it, let us for them;" and a few years ago it meant the death of several Koitapuans.

When new sago canoes come in from the west the natives collect splinters from each of them, and the following year, when all are in the Gulf, and the time is nearing for the return home, the sorcerers give it out that they must be considered. A morning is set apart, and a large quantity of food is collected, on the top of which may be seen tomahawks, beads, tobacco, tocas, spears, and pearl shell. The sorcerer holds in his hand a piece of an earthenware pot, in which there is a parcel containing the

splinters, and over which he is supposed to "meamea." Lost canoes are always easily accounted for by these sorcerers. They have often tried to exorcise the white missionaries and teachers, but to no purpose; they had to give up saying "God is strong." Many in the Motu tribe have thrown them over, and of late years their revenue has been little.

A short time ago the following happened at a village about four miles from Port-Moresby:—An old widow, with her two sons, left the village of Kevana, forty miles from Port-Moresby, where a part of the Koitapu tribe live, and went to Padiri to live. She was always looked upon as a great sorceress, and her sons assisted her. Unfortunately, she boasted constantly of her great power, which was very displeasing to the chief Gheita and others. During the early months of last year we had no rain on the coast, and many of the plantations suffered in consequence. The old lady and her sons did not try to hide their having something to do with the drought, and for a long time they were kept in food and other things; but, no rain coming, it was too much for Gheita, and he determined to get rid of so obnoxious a personage and her sons. She was known to have a large bag, containing all kinds of food, which she kept buried near her house. She told them she kept it to prevent rain, and to show them that they had no power, that power of that kind rested with her. Gheita must have the bag. One morning very early he came with a pig to her, and begged her to give up the bag and all that it contained. After some hesitation one of the sons was sent for the bag, and Gheita, taking it, scattered the contents all around. The pig was killed and divided, the elder son went with his wife to a plantation to get food, the mother was under the house with a number of other women, and the younger son in the house. Gheita with two others followed to the plantation, and arranged when he had done *his* work he would shout, and then those in the village would do theirs. On reaching the plantation, he asked the widow's son for a smoke; the man went aside to his bag for tobacco and a leaf, and whilst engaged in preparing the pipe, Gheita rose, lifted his spear, and sent it clean through him, the other two doing the same. He then gave the long signal-shout, and those in the village began; the old woman was soon despatched, but the son in the house defended himself for some time, but was overpowered and done with. Friends (?) came, and took up the bodies and buried them.

An influential man from Port-Moresby, visiting the village the same day, was told of the murders by Gheita himself, who also said to him—"Tell Tamate (Chalmers) not be angry, but I could stand it no longer, and now it is done I am glad, and so must every one else be." I sent him word that I thought he should be hanged.

There is a place in the bush near to Port-Moresby sacred to the Koitapuans, where no one ever treads; to do so would be instant death. Such places there were in many of the South Sea Islands. The name of this Koitapu place is Varimana. Long ages ago, mighty men went inland to Sogeri, and carried away a very large stone. On the way down many died, and when the stone arrived near the coast range, the whole tribe begged that it might be left at Varimana, lest all should be exterminated. Long after it was carried to the Koiari, and they too died in large numbers. Again it was returned, and buried at Varimana, close by a young tree; the tree has grown very large, and now the stone is quite covered by it, but no one ever goes near the place. The stone before burial was carefully wrapped in native cloth, and bound round with well-made twine.

Such was the story often told from generation to generation. When the hunting season came round, and the grass in the vicinity of the tree was to be burned, Mabata, a great chief and sorcerer among the Koitapuans, might be seen clearing a wide space so that the fire might not approach near the tree. A threat by Mabata to dig up the stone and turn it over would at once strike terror into the whole Motu tribe, and many large presents would be brought him.

Time after time we tried to persuade Mabata to let us see the stone, but not until last year were we able not only to see it, or rather *them*, but to secure them. I offered the chief what was to him a very valuable present, and I accompanied him inland. On arrival at the tree he walked round it, and then asked if I was not afraid? On my replying—"Certainly not," he got a pointed stick, dug down a little distance through very hard soil that did not appear to have been touched for a very long time, until he came on a piece of an earthenware pot which covered another piece, in which were two small pebbles—the source of all the discomfort of many generations. He was very loath to let me have them, but after some persuasion, and leaving tobacco as a present for the spirit, I was allowed to carry them away.

On showing them in the evening to a Christian chief, once a robber chief, he, with great indignation, said—"And is that what we have all been afraid of? for that we have given these liars our best pigs, best axes, best tocas, and so have all our ancestors?"

For many generations the old people of Rarotonga (one of the Hervey Group in the South Seas) spoke of a stone seat—Fenoo-anga a Tau—that was long ages before covered over by a large Tamana tree. The grounds were sacred, and none carelessly trod there. To approach was the priest's place, and he only, crouching and uncovered. When a limb of the tree fell it was supposed that some one of the chief's family would die, and on several occasions such was the case. In the year 1867 the tree itself fell, and soon after the King Daniela died, leaving office to my friend Abela. When it was known that the tree was down, people from all parts came in to see for themselves the truth or falsehood of many generations, and there, sure enough, was the stone with the short back rest. Many times I have seen it and sat on it. Abela gave me Tuarea (the name of the large tree) to do with it as I liked, only he could not assist in cutting it up. Having at the time many students, fine young men anxious for work, they in their odd hours cut it up into logs, and the school children sledged it up to the mission ground. Only the root was left, which was afterwards used in burning lime. A few months passed, and I gave orders one morning after classes to roll out the best log and get it over the sawpit. This was done, and I had just returned to the house when a native came running to me, saying, "Makea Abela is dead." The night before I spent an hour with him in front of his house, and he was then in excellent health. That same morning I heard of him threatening some of his people. I ran over, and found him in the bush quite dead. He died of heart disease. Many natives said it was Tuarea. "Ah, well, we shall make his coffin from it." I ordered the morning's log to be rolled back and made into a coffin. The stone and tree superstition is very common in Eastern Polynesia.

Although the Motuans are afraid of the whole Koitapu tribe, there are two men of that tribe living in Redscar Bay whom they fear more than all the rest. Maba of Lokurukunu holds great power over the north-west wind, rain, and sun; and Taru of the same place holds the south-east wind entirely in his power. To these presents were constantly brought. When about to start for the west on a trading voyage, Maba was given a large present that

he might not send the north-west wind, and Taru one quite as large that he might continue the south-east. When the returning season comes—end of December or beginning of January—Taru was solicited to stay the south-east, and Maba to give the north-west wind. When planting yams the Koitapuans, holding a stone in the left hand over the seed, pour water on the stone with the right, and allow it to fall all over the yams to be planted, repeating very quickly the following:—

Asinavari daudau (repeat three times).
Huevara daudau ,, ,, ,,
Bedovari daudau ,, ,, ,,
Naevari daudau ,, ,, ,,
Eogovari daudau ,, ,, ,,

When the yams are just above the ground, the following is repeated in the plantations:—

Sinari kenikeni (repeat three times).
Hueri kenikeni ,, ,, ,,
Kuela kenikeni ,, ,, ,,
Naera kenikeni ,, ,, ,,

Mabata, the chief already mentioned, a great man in the tribe, and a kind-hearted fellow, though a great sorcerer, gave me the following prayer used by him when he hears there is going to be fighting. He says, when he uses it, that the fighters' hands hang down with weakness, and their knees tremble:—

Tuanugu i ae mai (repeat three times).
Komanugu i ae mai ,, ,, ,,
Vaugu i ae mai ,, ,, ,,
Korubuie (repeat twice).
Tuauru e ae a ,, ,,
Gorigori e ae a ,, ,,
Kuru e ae a ,, ,,
Gaubu i ae ,, ,,
Suuri i ae mai (repeat three times).
Guboioboio (repeat four times).
Koieri gamia a (repeat twice).
Gairiaki boioboio ,, ,,
De umu ba ba ,, ,,

It is gone over and over again—truly "vain repetitions."

In my reading of Lubbock's works, with those of the well-known missionary Dr. Turner, I selected a number of questions, which I try to have answered when visiting a new tribe; and it will tend to increase your knowledge of the New Guineans if I just throw a few of the answers into readable form.

In reference to marriage, it is much the same as with other uncivilised tribes. They are sometimes betrothed from before birth, parents arranging if son and if daughter they will be married, and then presents are exchanged between families. Very frequently betrothal takes place just after birth. Some are never betrothed. On betrothal after birth, the parents of the boy begin paying for the girl, and will give her parents what they can, as pigs, sago, arm-shells, &c. The girl's parents also begin taking wood, water, and food to the boy's parents, and will continue doing so until the boy and girl are old enough to be married. It frequently occurs that neither cares for the other, and the lad chooses another girl, and the girl another lad for husband. Then there is trouble, until the girl's husband has made payment to the boy or his parents.

Frequently, when a girl's father is anxious to have a pig or a large parcel of sago, he will give his daughter to anyone who will give either of these, only on marriage there will be an additional payment of arm-shells.

The girl, on going to her new home, will receive from her parents as dowry a fishing net, a kangaroo net, a few spears, pots for cooking in, chatties to carry water, and a few petticoats, with a net bag (kiapa) to carry food in. The young man and woman will sit and eat together just after her arrival at his house, which is considered marriage. For years husband and wife will remain loving and making fun (hegera bada) with each other, but when they grow old and have many children there is not much of it; they sit together and speak friendly, but do not "hegera."

A husband can send away his wife if she does not please him, being too frolicsome, too lazy, and having bad plantations, or if she cannot make pottery, which is made entirely by the women, or if she is a bad cook, and given to gadding about. For any of these he can order her away, and the people will say "Quite right." The wife also can leave if she is displeased with her husband, and often it is done. Sometimes, because of a quarrel, the wife will leave, and after a while the husband will go with a present to her friends and beg for his wife, when new promises are made, and again they

live together. Should a wife who has left her husband be taken by another he must pay for her, not to her relatives, but to the late husband and his relatives. Some marry from pure love. When eating out of that first dish it will be noticed how they sit—if side by side and lovingly it is good, if back to back, or one turns his or her back to the other, it is bad, and will be sure soon to end. Sometimes, not often, a woman has left her husband, gone with another, then repented and returned to her former husband, and if very repentant is received.

For two brothers or two men to have one wife is quite unknown, but polygamy exists amongst some tribes more than others. It is very prevalent around Aroma, Hood Bay, Maiva, Elema, and Namau, the last worst of all, where many strange customs exist that I dare not touch upon at present. In and around the China Straits, and west to Dahuni or Orangerie Bay, a man will not, if he can possibly help it, speak to or meet his mother-in-law; should she be visiting her daughter, and hear her son-in-law coming in, she will rush out at the other end of the house. A wife will act in the same manner with her father-in-law.

In some tribes when a child is born, the husband shuts himself up, and for some days will eat nothing. In a few tribes on the coast just after child-birth, the mother with her babe will leap into the sea. When the babe is a few days old the nose is pierced, and were the child to die without, it having been overlooked, it would be done immediately, so as to secure its happiness in Tauru —the place of departed spirits.

Children are fed often with things of strength (so that strength may enter the child), namely, a large strong pig, strong wallaby, or very large fish. Twins are very much disliked, relations saying it is pig-like. After birth of the child, husband and wife live apart until the child is weaned, which does not often happen until it is able to run about. Should a child be born before the other is big and able to run about, all will be ashamed, and will speak of the woman as a pig.

They have different forms of salutation. In some tribes they rub noses up and down, in others across. Inland, the general salutation is to touch chins. Altogether, the Papuans are less demonstrative than the Eastern Polynesians. I have never met a tribe in New Guinea who kiss the hand, but in the South Seas it is very common, out of respect. Only at the east end have I found any word for thanks. In the D'Entrecasteaux group they

say *Iannedo.* In Milne Bay they say *Teinani,* and at Heath Island, and the neighbourhood of China Straits, it is *Kagutoki.*

I do not think the Motuans have any knowledge of one Great Spirit, but the Dahuni, Aroma, Hood Bay, Kabadi, Maiva, Elema, and Namau tribes have. Certainly their knowledge is meagre; and although once a year they have a feast with dancing and singing, when they acknowledge a Great Spirit, yet they can tell you only a little about Him. They say He is good and kind, and in distress often assists them. They all believe in the spirits of their ancestors, and dread them much indeed, seeing that they can have no influence over those spirits. If spirits are angry they will interfere in fishing and hunting, cause famine, sickness, and death. There is nothing in nature which they worship. In Elema and Namau they make gods.

As death approaches, few are the friends in the house, only near relatives—and every heart-beat is watched with low wailing, not heard by outsiders. Whatever of value belonged to the dying one is now collected, placed near to the body, and there left. It may be, the flickering life is more prolonged than was expected, and a fancied hope springs up within, only to be dashed soon by the departure of that life from its frail tenement. Then, as the spirit has gone, and is resting on Era—a point of land about two miles off,—there is a long, loud wail—that of all hope gone. That is, I believe, the greatest of all human sobs—the sincerest wail of a hopeless heart—ever uttered.

Female friends then assemble, and, whilst the body is being washed and laid out, they sing what is called the *Orera*—a low, deep, wailing chant. The body when washed is then dressed in all its finery of life; if a fighter, the head is adorned with feathers, and the sihi (stripe of bark worn for trousers) is put on with the length hanging in front. The body has been rubbed over with the squeezed juice of the cocoanut, and not a little of that is mixed with red ochre, and the face is painted. Friends now come in, and for some time it is *orera,* so that near relations may be able to weep. They say at such a time the sorrow is so great tears will not come, and the heart (kudou) is like to break; so when friends are weeping and wailing it opens the heart, and the tears soon flow, and then there is relief. During the night someone will say, "Let us get our drums and go and sit with the dead, and comfort the mourners." The drums are got, and all appear, when the chief mourner, who has perhaps been lying on the corpse,

asks who are these, and is told—sometimes is told without asking —that they have come to remain and give comfort. The mourner or mourners sit up by the dead, and then the drumming begins. First they sing the praises of the dead, his or her goodness, strength, and wisdom; and then it is a livelier strain, such as they sing when on their trading voyages. As well as giving comfort, the drum-beating and singing are supposed to attract the attention of those in Tauru (Avaiki of Polynesia or, beyond, in space), and they come and find out what it is, and returning give information to those of the relations there, who come and give their assistance for the removal of the spirit to Tauru. The singing during the night is conducted by the men, and carried on until after sunrise. They also occasionally during the night beg of the dead to be with them always, especially in planting, hunting, and fishing. In the morning food is cooked, and the singers and drum-beaters are fed. At times there is a large quantity of food, and if the relatives can afford a pig it is killed and divided.

Friends, some time after daylight, arrange amongst themselves to dig the grave without informing the immediate relatives. The grave is dug in the main street, in front of the deceased's house, a shallow grave, of only two feet deep. During the morning the body is placed on a mat in the grave, and a plank placed over all. Over the grave a house is built, and the chief mourners live there for about two moons and a half. It is necessary that they should live there, to show their great love for the dead. Should a wife or husband, or child or parent, neglect this, they would be spoken about as unfeeling and unloving, who never *smelt* their relative. For four days there are ordinary feasts given, and on the fifth a large one, after which all friends go to their homes. Those living in the house over the grave use the juice from the body to mix with charcoal, made from cocoanut husk, which is used in blackening themselves, when they really do look hideous. They never leave house during the day, but at night go out. When the time comes for real burial, all the bones are taken up, carefully cleaned with water, rubbed with oil, and painted with ochre. A small feast is cooked for relatives, and the bones are placed in a new mat and laid in the grave, when all is covered with earth.

And what of the spirit? There are various stories, but the most prevalent is that on leaving the body it goes to Era, where it rests before going to Tauru. There a platform of sticks is made, on which the spirit is placed, with a large fire underneath,

which is kept burning for two days and two nights, when the spirit is dry and much lighter, and it then enters into the great Tauru country, where it for ever remains in happiness, marrying and giving in marriage, and bearing sons and daughters, planting food and getting abundant returns—no sorrow, but all joy. Spirits have no noses, but every other member is right. Why they should be without a nose I am unable to find out.

In former times the Koitapu tribe did not bury, but placed their dead in caves or on ledges of rock. Some time ago I visited one of these places. It was quite away from the haunts of men. Several skulls and a large quantity of bones lay about. They laid the dead on a plank, carried it in, placed it on the ledge underneath a large piece of overhanging rock, and then left it. Of late years they have adopted the Motu custom, and bury as the Motuans do. The Koitapu spirit-land is away back in the mountains.

Taroa, Manukolu, and others on the coast ranges keep their dead in the house until falling to pieces, to the great annoyance and discontent of those who happen to be to leeward of the houses. The juice of the body they use, as the Motuans, to blacken themselves with. When the body is "falling to pieces," the bones are carefully washed; the smaller ones are strung together, and carried about often as a necklace, and the larger ones buried.

Kabadi and Elema bury deep, and have no bone-cleaning, only they have all the feasting, and for long live in houses built over the grave.

Namau bury in very shallow graves, and leave the head exposed, so that friends may often come to the relatives and see it. When the head separates from the body, it is well cleaned and carried home, there to be kept, the teeth extracted, to wear as ornaments on the ear or round the neck.

Koiari leave the body in the house, and frequently leave the place and build elsewhere. Once when travelling inland we came to a deserted village, and in two houses found skeletons.

Sometimes they keep the body, as at Kaile and Kapakapa, and wrap it in mats, hang it over the fire to dry, and, after a time, put it away in the hole of a rock close by the village. They also clean the bones at other times, and carefully bury them, placing spears and cooking pots over the grave.

Hula do the same as Kaile and Kapakapa in some instances, in others they bury and never dig up.

Kerepunu, Kalo, Babaga, and Kamali all bury deep, sometimes build houses over the grave, and there sleep, but do not again disturb the body.

At Dahuni they have both plans. Some are buried in a sitting posture, the upper part of the head exposed, and covered with an earthenware pot. In about two months a large feast is prepared, and the head is taken, well cleaned, put in a basket, and hung up in the house. Others are put on a kind of platform and there left, except the head, which is taken and done with as above.

All natives are great believers in dreams. In sleep the spirit leaves the body and wanders, and if it meets with those that are dead it is that it has got to spirit-land, and is holding commune with those long since gone hence. If it has travelled amongst the living it may have seen something of use, heard something likely to take place, and so returns to the sleeping body. Such are dreams, and they are often acted upon.

I shall now close this paper by naming a few of the Motumotu tribe's amusements:—

Avahu.—Two sides throw pieces of wood at one another.

Ipa.—Ball made from pith of a banana tree, or a bladder, kept in the air from hand to hand by a crowd.

Aposieka.—Sham fighting with small bows and arrows.

Karoa.—Dancing in ring, and then pass under joined hands, the last detained.

Lavi.—Two join hands, a third sits on them, and is tossed up and down until thrown off.

Hohore.—Hide and seek.

Koa.—Hide something in sand, others come and try to find it.

Laka.—Make a mound of sand, and jump over it without touching the top.

Kaukavare.—Chase and touch.

Morapaisavare.—Cock-fighting; two sit down and try to overturn one another with feet.

Ori.—Kite-flying.

Fareafarea.—Stilt-walking.

Mavaesika.—Small canoe sailing.

Rakanei —Football.

Ope.—Shinty or golf.

Poioki.—Swing from tree.

Ita.—Pig; get hold of a boy and make him hang on, as a pig, to a stick, and carry him about.

Mori.—A number of girls carry one on a plank, all singing and shouting.

Foipea.—Wrestling.

Mautoa.—Chasing and trying to strike with short stick.

Sugautera.—Chase, and trip or try to throw down.

Levaki.—Dancing in a ring, with one in centre, who tries to break through.

Kerori.—Sitting in a ring and catching hold of ears, singing and swinging in concert.

Farisaboi.—A number sit close together, make a pinnacle of hands, sing, and sway them up and down.

Ase.—The members of one party stand compact together, and are attacked by another party, who try to break into or throw them down.

In the afternoons and evenings the time is mostly spent in such games.

VI.—*Report from the Conference of Delegates of Corresponding Societies at the Birmingham Meeting of the British Association, September, 1886.* By Henry Muirhead, M.D., LL.D., *Cambuslang.*

[Read 15th December, 1886.]

Having been appointed to attend, on behalf of this Society, the Conference of Delegates of Corresponding Societies in connection with the British Association for the Advancement of Science, at that Association's Meeting in Birmingham, I, in September last, attended the two Conferences held, and have to report:—

At the first meeting the chair was occupied by Professor A. W. Williamson, General Treasurer to the British Association. Various proposals were brought forward; among others, suggestions as to investigations concerning Injurious Insects, Erratic Blocks or Boulders, British Barrows, and other Prehistoric Remains.

Professor Lebour remarked that in many local Societies there were engineers connected with large works who might make useful investigations, which would be facilitated if backed up by the British Association. He therefore hoped that other subjects besides Natural History, Geology, and Anthropology would be recognised.

Captain Galton explained that the object of the Conference of Delegates was to bring the corresponding Societies in direct communication with *all* the Committees of the British Association, to which the local Societies or individual Members of these might render assistance. This, of course, could only be effected by degrees; but he suggested that, as a preliminary step, it would be found useful to place the Delegates on the Committees of those Sections in which they, or their Societies, had the most interest. Dr. Williamson supported this suggestion, and it was agreed to.

The following resolution, framed with the object of keeping the Corresponding Societies informed of the work being done by the British Association Committees, was moved by Dr. Garson, seconded by Captain Galton, and passed unanimously:—"That the Secretary of the British Association be requested to send a list of the several Committees appointed by the Association to each of the Delegates of the Corresponding Societies, or to the Secretaries of those Societies, as soon as possible after the meeting

of the Association, together with a copy of the proceedings of the Conference of Delegates."

A copy of the lists and of the proceedings having been forwarded to me, I now exhibit them, and shall place them in the Reading-room for perusal by Members.

At the second meeting the Chairman, Professor Boyd Dawkins, suggested that the best mode of procedure would be to take the Sections of the Association *seriatim* and hear the recommendations forwarded, and remarks from the Delegates, respecting the lines of investigation in which the local Societies could take part.

No recommendations came from Sections A (Physics) or B (Chemistry). On the invitation of the Chairman, Mr. Mott suggested that much useful work might be done by local Societies in recording systematically the appearance, position, direction, &c., of luminous meteors. Mr. White remarked that Societies that were favourably situated might undertake systematic observations of local Tidal and Magnetic phenomena. Mr. Heywood stated that many valuable Meteorological observations were buried in the log-books of steamships, and suggested that some of the local Societies might render good service to Meteorology by examining such books and making records of important entries. Mr. Hopkinson pointed out two ways in which Meteorological and Phenological Science might be advanced:—(1st) There might be observers of Rainfall and other Meteorological phenomena in different parts of the country who did not communicate results to Mr. Symons [or to Mr. Buchan], but who might be prevailed on to send reports; (2nd) Observations of the times of Flowering Plants, first appearance of Birds, Insects, &c., might be forwarded to Mr. Symons, Secretary, Royal Meteorological Society, by observers who had not been in the habit of so doing.

From Section C (Geology) there were three recommendations:—(1st) In reference to investigations regarding Sea-coast Erosions; (2nd) Regarding circulation of Underground Waters in permeable strata, and the quantity and quality of the Water supplied to Towns; (3rd) Regarding records of the position, height above sea, lithological characters, size, and origin of Erratic Blocks.

The following are the names of the respective Secretaries of the Committees to whom information may be transmitted:—

Underground Waters—C. E. De Rance, F.G.S., 28 Jermyn Street, London, S.W.;

Erratic Blocks—Rev. H. W. Crosskey, LL.D., 117 Gough Road, Edgbaston, Birmingham;

Sea-coasts Erosion—William Topley, F.G.S., 28 Jermyn Street, London, S.W.; and I add for

Meteorological and Phenological Observations—G. J. Symons, F.R.S., 62 Camden Square, London, N.W.; Alex. Buchan, M.A., Shandwick Place, Edinburgh, Secretary, Meteorological Society of Scotland.

Professor Lebour, College of Science, Newcastle, stated that for some time a Committee had been engaged on the subject of Earth Tremors in their possible connection with Mine Explosions. The more extensive the area over which such observations are made the more valuable they would become. The cost of expensive instruments would be lessened if large numbers were used. He will be glad to afford any information.

Section D (Biology).—In reference to the *Preservation of Native Plants*, Professor Hillhouse, of Mason's College, Birmingham, stated that, in reply to inquiries, he had received details of the disappearance of between two and three hundred plants from localities. He had counselled the omission of the localities of rare plants from the local floras published.

In reference to *Local Museums*, the Chairman stated that in this country they were generally in a deplorable condition. The first thing to be done was to exclude from such all specimens not truly local. He considered that this country was much behind Germany, America, and France in the matter of Local Museums.

Section H (Anthropology).—As a Member of the Committee appointed "to ascertain and record the localities in the British Islands in which the evidence of the existence of Prehistoric Inhabitants of the country is found," I shall be glad to receive any information, or communicate with any lady or gentleman, on the subject.

I have abstracted these items from the report that they may be brought under the notice of Members who may not have knowledge of, or opportunity for consulting, the printed papers in the reading-room.

Professor Meldola, 21 John Street, Bedford Row, London, W., is Secretary of the Conference of Delegates.

NOTE.—I ought to mention that the Delegates were placed on the Committees of Sections, in compliance with the suggestion contained in the fourth paragraph of this Paper.—H. M.

VII.—*On the Progress of Technical Education, with Special Reference to the Glasgow Weaving College.* By DAVID SANDEMAN.

[Read before the Society, 15th December, 1886.]

IN a paper by Mr. E. M. Dixon and myself, read before the Society in 1882, on "The relation of the School to the Workshop," we avoided saying anything in favour of the former superseding the latter in the execution of work.

In the paper which I shall now have the honour of reading, I shall endeavour to prove that the school fulfils, however, a very important and necessary part in Technical Instruction, of which the numbers who are now anxious to avail themselves are conclusive evidence; and I shall likewise enumerate various facts which show the progress which has of late been made in this direction, by the increase and extension of the opportunities for carrying out so laudable a desire.

The successive Exhibitions which have taken place, and which have been patronised by the highest authorities, have from time to time been the means of making known to us wherein other nations excelled us—to wit, generally in those manufactures or works of art in which a more intimate acquaintance with the principles of design was evident; and it was no doubt the knowledge of this which led the Prince of Wales to inaugurate the Technical College at Bradford, and otherwise to promote the progress of industrial education. The Universities have likewise shown a praiseworthy interest in the movement, by the endowment of chairs dealing specially with the subject.

The City of London Guilds generally have shown themselves worthy descendants of their predecessors in the reign of Queen Elizabeth, when, as Froude stated, some years ago, "England was stirred from end to end, by the threatened invasion of the Spanish Armada, fitted out by Philip of Spain. Queen Elizabeth appealed to the loyalty of her people, and ships were fitted out, volunteers flocked to her standard, and even the City Companies and Citizens of London brought their treasures and plate, and offered them to

the Queen for the defence of the country." In like manner they have now come forward, animated by the same patriotic spirit, to ward off the great industrial invasion threatened, and to some degree effected, by our foreign rivals.

For this purpose they—but especially the Worshipful Company of Clothworkers—have, by the exercise of most princely liberality, been the means of establishing Chairs in Technical Colleges and Schools in England, and of otherwise promoting the cause in Ireland and Scotland, by largely contributing to the formation of schools, and encouraging their students, by awards of medals, diplomas, and money prizes. They have thus greatly strengthened the hands of our manufacturers in their efforts to meet and to counteract the competition by which we are in danger of being beaten in some branches of industry, and they have succeeded, by their generous action, in impressing the public mind with the necessity incumbent on the employers of labour in this country to avail themselves of the means whereby our foreign rivals have attained an excellence which threatens to lessen our pre-eminence as a manufacturing nation.

Let us look for a little into what has been done abroad; and in drawing attention thereto, we cannot but admire, particularly among our German neighbours, the thorough and complete organization of their Technical Schools, of which it is said, that it was the schools as much as the needle gun which were instrumental in conquering the French. It is well known that it was the defeat of the Germans, at the battle of Jena, which aroused the national spirit, and led to the establishment of the Technical Schools, which have gradually instructed the German people, and enabled them after so many years of indefatigable perseverance to obtain the mastery over their French adversaries. This it has taken them sixty-four years to accomplish. The growth of their strength has been slow, but it is all the more likely to be permanent in its results.

"The Weaving Schools of Germany," says the Report of the Royal Commission on Technical Education, "are among the best of their kind that we have seen; we select three which represent the best types of these schools. The first is the Spinning and Weaving School at Mulhouse, which is the best illustration that we have seen of instruction in cotton-spinning, while it is also complete in appliances for power-loom weaving, and possesses an extensive variety of looms from the best makers in competing countries;

the second, is the Higher Weaving School at Chemnitz, in Saxony, one of the best examples of a school for teaching the application of designs to the loom, and for varied instruction in the weaving of many kinds of fabrics by hand- and power-loom; the third school is that which has been recently erected at Crefeld, at a cost of £42,500—of all schools we visited for teaching designing, the application of the design to the loom, the manual operations of weaving in the best makes of hand- and power-looms, and the dyeing and finishing of manufactured goods—this school is the most complete and the most important.

"There are 33 hand- and 27 power-looms; two engines—a 12-horse power compound steam-engine and a 4-horse power gas-engine; numerous class rooms and lecture rooms, and reading room, a museum of textile fabrics, with studios for designers, all lighted by electricity, supplied by two dynamo machines, driven by a 12-horse power engine in the basement. The school derives a portion of its annual income from the fees of the students, and the deficiency is made up by grants from the State, the Municipality, and the Chamber of Commerce. During the present year (1884) the deficiency is expected to be £3,000, which will be raised as follows:—

"The State (half the expenses up to a maximum of £1,500),	£1,500
"The Town, one-fourth,	750
"The Chamber of Commerce, one-fourth (from the profits of the silk conditioning house),	750
	£3,000

"The fees for weaving and dyeing instruction are, for Prussians £10, for other Germans £15, and for foreigners £25 a year."

It may be asked, How is it that a people like the Germans, already so heavily taxed to support their enormous military expenditure, are willing to undertake the maintenance of Technical Schools? Their reply is, that we, and other nations to whom they sell their productions, amply repay the outlay in the increased value of the goods produced.

Mr. Swire Smith, a member of the Royal Commission, states in a lecture recently delivered at Ripon:—"The Commissioners found that the Technical Instruction, which is acknowledged by the best judges to have been the main cause of the superiority of our rivals in certain manufactures, is almost precisely the instruction

which English Mechanics' Institutions were founded to give over sixty years ago. Now, mark the difference in their educational machinery and its results. The foreign Technical Schools have been built and equipped by Governments and municipalities, at considerable cost, for the sole purpose of training their manufacturers and artizans in the principles of the arts they practise, so as to enable them to meet the industrial competition of England."

I am glad to remark that the downward course of Mechanics' Institutes in this country has recently been arrested, and that a new departure introduced in a strictly scientific direction, the successful issue of which is notably shown in the excellent work now done by the College of Science and Arts in Glasgow, formerly the Mechanics' Institution, as also throughout England, especially where the Science element now prevails in all these institutions.

I might refer to what is being done in France and Switzerland, where great attention is paid to the teaching of design, which for many years has enabled those countries to excel us in the production of works of art of every description. There is in Zurich a Polytechnic School, the completeness and extent of which may be estimated, when it is stated that there are upwards of 200 distinct courses of lectures, given by 45 professors and 13 assistants. Its budget in 1876 was:—

Annual Federal Subvention, - - - - - -	£13,880
Annual Subvention of the Canton of Zurich, - -	640
Annual Subvention of the Canton and Town of Zurich, for the purposes of the Natural History Collection,	176
Fees paid by Students, - - - - - - -	3,794
	£18,490

The total annual expenditure was a little under £20,000. In addition to this, a total of nearly £20,000 has been bequeathed, and a sum of £50,000 has been voted by the Federal Council for the extension of the chemical laboratories in the school.

In Paris there is the "Ecole National des Arts Decoratifs," where 16 professors give gratuitous tuition to about 800 pupils, the greater number being above 14 years old, who, before gaining admission, however, must prove that they are able to profit by the instruction given therein. The budget of the school is £4,236, towards which the Ministry of the Fine Arts contributes £3,796, and the City of Paris, £240, the balance being derived from sundry

legacies. Schools of Art of a similar kind exist in nearly every provincial town in France. In Lyons the municipality grant £2,280 a year to their Art School.

In Roubaix a new Technical School is being built, the probable cost of which will be at least £80,000, towards which £48,000 will be contributed by the Government Department of Fine Arts, and £32,000 by the municipality. It is expected that the annual cost of maintenance will not be less than £3,200.

In Ghent (Belgium), in 1847, there was extreme depression of trade, and the linen branch, for which the town had become particularly famous, threatened to leave it altogether. The importation of linens from other countries had become so extensive, and their cheapness so severely threatened annihilation to the staple industry, that a loud cry arose for the Government to protect the manufacturers by the imposition of prohibitive duties. The Government wisely, however, turned a deaf ear to the clamour of the population, and said that they were determined not to protect ignorance, and would much rather encourage intelligence. Acting upon this resolution, they established Technical Schools, the good effect of which was presently manifested in the restoration of confidence in the industry of their own artizans, when properly directed; and from that date, a revival of their trade commenced, and has continued.

In Canada and the United States there exist numerous Science Schools—in Philadelphia and Boston, Schools of Design; and a beginning has also been made to establish a Weaving School in Philadelphia; but there are numerous high-class institutions for technical and scientific training, in mining, civil and mechanical engineering. Mr. Mather, in his report addressed to the Royal Commission, says:—"I am of opinion that in these branches, judging from my own observation, there is nothing better of the kind, though such institutions are more numerous at present in Europe." I, myself, visited three of these Technological Institutes —namely, the Rensaeller at Troy, the Stevens at Hoboken, and the School of Technology, Boston; and on my return from America, at a discussion in this Society in the Session of 1876, I made reference to them, observing that they had commenced technical work in metallurgy and engineering, to which an eminent engineer of this city replied—"that what our friends in the States were doing in this respect was no guide for us; they having no large shops such as we had, were obliged to have Technical Schools,

whereas we could give our youth a more thorough knowledge of engineering in the workshop."

I bowed at the time to this gentleman's opinion, as I felt that he was a far more competent judge of the subject under discussion than I could pretend to be; but of late years, I find that another local engineer, of equal eminence, had sent one of his sons to the Technological Institute at Boston, and upon my inquiry as to the benefit derived by his attendance there, I was informed by his partner, in his own words:—"15th November, 1885. Mr. H. J. M. made very great progress at the Institute of Technology in Boston, Mass., and a year ago brought home samples of handiwork which surprised us all. I would have been pleased to see a three years' apprentice here produce what a year's teaching enabled him to do. There is no doubt we must have more manual training schools here."

I have already referred to the College of Science and Arts. Anderson's College fully maintains its reputation as a scientific institution, while we have also in our midst the Allan Glen School, well known in the educational world as a pioneer, introducing Technical Instruction into day schools for boys. In this new departure it has been eminently successful, and probably its example will be followed by others in Glasgow. An especial feature of this school is workshop instruction in the use of tools. The school is divided into three departments, (1) the Elementary, consisting of three classes; (2) a Secondary, also consisting of three classes; and (3) a Technical department, in which the science subjects in the advanced stage are taken, together with practical exercises in the use of tools. A period of two years is devoted to this workshop instruction, with very satisfactory results. I hope that I shall be excused going into this detail, owing to the very practical character initiated by the Allan Glen Institution, forming, as it does, an excellent basis from which the higher Technical Instruction can spring.

The Science and Art Department, South Kensington, is likewise bearing its full share of Technical work, by granting payment on results, which increases steadily, there being at present upwards of 150,000 students in Science classes under this Department, which shows a large increase over the number in previous years. This increase is chiefly in subjects which are of special value in Technical Education, such as Mathematics, Machine Construction and Drawing, Mechanics, Chemistry, and Building Construction.

The work done in these classes bulks mainly in large centres of population, and in those places where there are schools in which systematic instruction in allied branches of science can be given, showing that the quality, as well as the quantity, of the instruction is improving. Some idea of the aid given by the Department can be gathered from the fact that three institutions in Glasgow obtained amongst them more than £3,000, while the total amount earned in this city will be above £6,000, as the result of this year's work.

The Educational Endowments Commissioners have issued a scheme under which the existing endowments shall be amalgamated, and henceforth administered by the governing body constituted therein, incorporated by the name of "The Governors of the Glasgow and West of Scotland Technical College." I have no doubt, by availing themselves of all the present teaching power, and extending it where more is required, that greatly increased means for the promotion of Technical knowledge will result.

In 14 schools in Bavaria, Belgium, France, Germany, Holland, and Switzerland I find that the funds for their erection, equipment, and maintenance are provided as follows:—

The Municipalities contribute - - -	about 11	per cent.
The States or Governments contribute -	,, 74	,,
The Students' Fees amount to - - -	,, 15	,,
	100	

This is a proof of the value attached to Technical Instruction by the authorities in the countries named.

I turn now with pleasure to the action of our School Board, in having included Drawing as one of the branches of education, which will greatly facilitate the work of the Technical instructors, by enabling the pupils who may come under their tuition to follow the lessons given in the lecture room with greater intelligence. In illustration of their work I may quote the words of Mr. Kennedy, in a communication kindly sent to me, dated 26th October, 1886:—

"Ever since the Board had day schools, Drawing has been taught and has been a prominent subject. In appointing teachers, the Board made sure that one or more in each school had certificates to teach Drawing. As the result of the Commission on Technical Education, the standard in Drawing has been raised, and a much larger grant offered; a special examiner from

the Science and Art Department now goes to each school; there is a regular graded system of instruction, as in reading or any other branch; the qualifications of the teachers have also been raised; certain time must be devoted to the teaching of Drawing, and it must be taught regularly over all the school year. A premium of £5 is offered by the Board to every pupil teacher who obtains the full D certificate. This has had a considerable influence in interesting the pupil teachers in the drawing classes. In nine schools, evening drawing classes are carried on, and already there have been enrolled 650 students. Design is taught in all the advanced classes. The average number of scholars, in the Glasgow Board Schools, attending Drawing, as at September, 1886, was 49,055. In most of our new schools, rooms have been specially built for the teaching of Drawing, and furnished with all the modern appliances and apparatus, and no sooner are any of them opened for classes than they are largely patronised."

I would recommend any one who has not seen the accommodation provided for instruction in Drawing, Design, and Modelling, to visit the Kent Road and Townhead Schools. The facilities for teaching Drawing provided by our School Board will naturally lead such of their scholars as desire excellence, to attend the classes of the Haldane Academy, where the highest instruction in those subjects is given by an eminently qualified head-master and staff. The Trustees of the Weaving School, desirous of enabling their students to have the opportunity of benefiting by this instruction, have formed a class under the superintendence of Mr. Kirkpatrick, one of the Academy masters, which will entitle the students to examination by the Kensington Science and Art Department, and to compete for its awards. They have to acknowledge the readiness with which Mr. Newberry, the head-master, co-operated with them in effecting this desirable result, and they fully anticipate great advantages to follow the introduction of this essential element in all Technical Education.

In looking over the different Schools of Art throughout the kingdom, I was struck with an account of the various means by which the Birmingham School has been established. I give the following extract from a letter which I received from its Secretary, in reply to my inquiry regarding its history:—

"Birmingham, 1st December, 1886. . . . . Until September, 1885, the Birmingham School of Art was conducted

by a private body of subscribers. In November, 1881, Miss Ryland and Messrs. R. & G. Tangye offered £20,000 for the building of a new school, on condition, that on the completion of the building, the management of the school should be undertaken by the Town Council. . . . . Mr. W. B. C. Colmore gave a piece of land 1000 square yards in extent—a valuable site in the centre of the town. These offers were accepted by the Council, and the subscribers to the school concurred in the transfer of the same to the Corporation. An alteration on the plans led to an additional cost of £1,254 5s. 4d., which was defrayed by Messrs. Tangye, making the total cost, *exclusive* of the value of the site, £21,254 5s. 4d. A sum of £3,520 has been spent in furniture and fittings. . . . . For maintaining the School of Art and its eight branches, the estimate of expenditure over receipts, approved by the Town Council for the present year, is £2,135. The necessary funds are provided by the Free Libraries Act, in which the authorities took power to raise the assessment rate to cover the expenses of the Central School of Art, with its eight branches, the Central Free Library and five branches, News-room, Museum, and Art Gallery. The rate is 2·06d."

The importance of Drawing cannot be over-estimated. The Commissioners on Technical Education had recommended "that Drawing and Writing should be considered as one subject in elementary schools."

Sir Philip Magnus said at a recent conference in London, "that in many of the countries which he had visited models had been placed before the pupil at the very commencement of his work; it was thought advisable to familiarize the pupil at the outset, however young, with the power of representing on paper the things themselves which he saw before him; in fact, the difference between drawing from a copy, and drawing from a model, was very much like the difference between learning a science from books, and learning it from nature. . . . . He was happy to be able to say that the appeal to foreigners for designs was very much less than formerly. Not long since the designs for nearly all the lace fabricated in Nottingham came from Paris, but now the large majority of the designs used in England were the results of work done in the Nottingham Art School. . . . . He was quite sure that manufacturers were short-sighted in not doing more in their own towns for

the promotion of Technical education; the remedy to alleviate the ill effects of the system of payments on results must come from the manufacturers rather than from the State. When they and other persons were prepared to put their hands into their pockets to support the Art and Science Schools, by giving fixed salaries to the masters, then, no doubt, the effect of payment by results would be less injurious than it was at present."

I would further quote from the report of the Technical Education Commissioners, that "drawing from models and casts should be taught in all elementary schools; . . . . and with regard to Technical instruction that local authorities shall be empowered, if they think fit, to establish and maintain Secondary and Technical Schools."

In reference to what Sir Philip Magnus has said upon this system, he admits it would be a complete revolution in our teaching, for which we are not prepared, and we must continue to retain this system. How would it do to effect a compromise by abolishing it in the higher Secondary or Technical Schools, by giving the head-masters handsome fixed salaries, and retaining it only in the elementary schools?

I must now give some account of the Weaving Department of the Glasgow Technical College. Erected in 1876-77, it was opened in September, 1877, and has now entered its tenth session. From its last annual Report it will be seen that the original building, including site and additions from time to time, has cost £5,037, subscribed by a number of gentlemen, not exceeding sixty in number; and I am glad to say it is free from debt. It is three floors in height, the ground floor consisting of vestibule, and two sheds, containing 27 hand- and 18 power-looms and beaming, with appliances for warping and preparing warps, &c., and an engine of 8-horse power, with storage for coals, &c. On the first floor, besides a private room for the Instructor, there is a Lecture Hall, capable of seating about sixty students. All the power-looms are the gifts of their respective makers, and an additional one, which was shown at the Edinburgh Exhibition, by Messrs. Hollingsworth, for which the gold medal was awarded, will shortly be presented to the School by them. The second floor forms the dwelling-house of the Instructor, Mr. Brown, who has for above four years occupied this position, with credit to himself and acceptance to the students. He possesses an amount of knowledge of the art of weaving rarely equalled, and probably unsurpassed;

and he is ably assisted by Mr. Light, a thorough adept in every detail, and by a young lad whose services are very valuable.

The hours of instruction are, for the initiatory class, Mondays and Thursdays from 9 to 11 and 11 to 1, and in the evening from 7 to 9; for the advanced class, Tuesdays and Fridays, from 7 to 9 p.m.; while both classes receive instruction on Mondays, Wednesdays, and Fridays, from 9 to 11 and 11 to 1 o'clock. A mechanic attends every evening from 7 to 9 to see to and keep the looms and machinery in proper working order. A very important duty is performed by the gratuitous services of a Visiting Committee, who keep themselves in constant touch with the Instructor and Secretary; indeed, there can be no doubt that the success which has attended the work of the school is greatly due to the harmonious co-operation of those in charge of it.

The promoters of the Weaving School calculated upon an average of 20 pupils, but the number exceeded this the first year and each succeeding year, making the attendance average 62, while this session there are 73; so that it may be held as firmly established as a branch of Technical instruction, and is supplying a want which has been felt.

Now, as to the occupation of the students, they are power-loom tenters, clerks and warehousemen, designers, sons of millowners and manufacturers, mill managers, mechanics, and young men whose occupation is not yet determined. Of the latter there are seven free presentations from the Trades' House and the Incorporation of Weavers.

I must now reply to a very natural inquiry, namely:—What is the object which the various students have in view? Generally, I would say, in reply, that they come to have their knowledge of textiles expanded, and go eagerly in for a certain amount of practice in hand-loom weaving and mounting. They appreciate the lessons in the analysis of cloth, at which they show great aptitude, being able in a short time to set down the movements of warp and weft on point paper, from which they then make entering and cording plans; as also pegging and cord cutting, a knowledge of which enables them to produce the cloth which they have analysed either in identical fabric or with variations.

This course of procedure is likewise greatly valued by tenters, who, although well skilled in the management of looms, are sometimes deficient in knowledge of fabrics, and the easiest method of producing them. They join the classes to obtain an insight of

looms, or parts of looms, which they have no opportunity of getting in the factories where they are employed. Some come to get a clearer idea of shedding by wypers, others to know more about dobbies and jacquards—each desirous of strengthening the weak points in his experience. Cloth inspectors, who can detect the faults in cloth, come to learn the causes of, and how to prevent, such imperfections, and to gain a general knowledge of cloth manufacturing. Power-loom beamers come for a general extension of knowledge of factory work, to enable them to attain a higher position; and mechanics, to learn how their work is applied, and by the knowledge of looms and cloth which they acquire, to rise to the position of tenters or managers. Such promotion, I have the satisfaction of knowing, has taken place among our own students. Of pattern designers we generally have a few; they come to learn how the design is embodied in cloth, and from the knowledge which they acquire of the construction of the harness and jacquard machine, they greatly enhance their individual work. Warehousemen and buyers and sellers of goods come for a general knowledge of how they are made, and to arrive at some estimate of their cost, of which we can well understand the importance. Manufacturers' sons and millowners' sons come to obtain a practical as well as a theoretical knowledge, not so readily acquired in their own works, which are usually limited to a particular class of fabric, instead of the variety met with at the Weaving School.

While I leave to others the advisability of extending the application of Technical instruction to other branches of industry, I would urge as a powerful argument in favour of its necessity to that of Weaving, the fact of the apprenticeship system having passed away. I wish to call attention to another feature in connection with the art of Weaving. I refer to the total extinction of the draw-boy, whose period of service to the weaver formed a sort of preliminary apprenticeship to the trade. As the draw-boy has ceased to exist and has almost been forgotten, I may explain, that previous to the adoption of the jacquard machine, he was a constant and indispensable assistant to the hand-loom weaver. His chief duty was to form the sheds in regular succession necessary to produce artistic designs on cloths of all descriptions. This he had to do by his own physical exertion, thus saving the weaver the work which he now performs by means of the jacquard machine, in addition to which the draw-boy was almost constantly employed in many other ways by the weaver, such as tying broken warp ends and broken cords of the simpler

sort, fetching pirns from the winder and weft from the warehouse,—indeed, being what is in some of our higher schools designated a "fag" or slave to his master, the weaver, from morn to night; and thus he naturally and almost unconsciously acquired a knowledge of the leading principles of high-class weaving before he was regularly apprenticed to the trade. Now that we have no such employment for boys, and this opportunity for teaching a useful art has passed away, a powerful argument is thereby constituted for the establishment of schools to supply the gap.

The Trustees receive letters from students who have attended the School expressing their grateful thanks for the earnest attention and zealous care devoted to them by Mr. Brown while under his instruction. With very few exceptions, all have derived substantial benefit, not only giving them pleasure in their work, but enabling them to fight the battle of life with more confidence as to its result, while the knowledge which they have acquired has been the means of raising their value in their respective fields of employment, and also in some cases of becoming skilled manufacturers themselves. Application is frequently made to the School for foremen, which has led to satisfactory engagements; and as the merits of the School become generally known it will be much resorted to by manufacturers in search of skilled assistance.

The Weaving School, with all its plant, being free from debt, it is only necessary to provide means for its annual support, which it is estimated will be about £250 in excess of the students' fees. This amount has hitherto been subscribed by twelve firms giving £20 each, and four giving £10 each, annually for seven years; and it is to be hoped that, now that the School is thoroughly established, the required number will come forward to occupy the place held by the sixteen firms who have been so generous.

The necessary companion to a Weaving School is one for Dyeing; indeed, in every instance the two classes of instruction are associated towards this end. The Trustees have pleasure in stating that they have received £1,931 13s. 4d., but as an additional amount of from £2,000 to £3,000 may be required, and as they wish to open it (as they did in the case of the Weaving School) free of debt, they would earnestly appeal to the citizens of Glasgow, but especially to the manufacturing community, to contribute the requisite amount, and thus enable them to carry out the remaining obligation to complete the means of instruction in the art of producing textile fabrics.

"Peace has its victories as well as war." Our national strength lies as much in the skill and efficiency with which we conduct our manufacturing industries as in our noble fleet and army; and if we do not grudge the expenditure involved in their equipment upon the latest and most approved system, to prevent our falling behind in the art of war, we surely cannot with consistency refuse contributing a comparatively small portion of our means to ensure our predominance in the arts of peace.

Since writing the foregoing remarks, I observe that at a meeting of the General Council of the Glasgow International Exhibition, 1888, the memorandum and articles of association were approved of, the principal point in which is the clause dealing with the disposal of any surplus, which it provides is to be handed over to the Corporation of Glasgow, to be applied towards erecting and maintaining a Gallery of Art, or Museum of Science and Art, or otherwise to promote science and art in the city. Let us hope that the surplus will enable the Council to carry out efficiently the purpose aimed at.

VIII.—*On Coal-gas: and the Coal Question, in its bearings on the Illuminating power of Gas.* By William Key.

[Read before the Society, 1st December, 1886.]

You are all familiar with the uses to which coal-gas is now applied. These uses, other than lighting, have of late years been increasing in an extraordinary manner; and when the merits of coal-gas are better understood, as being convenient, safe, reliable, easily brought to the full power required, and as easily and instantaneously shut off, while it is at the same time cleanly and economical, we may expect that its application to many more industries, and the extension of its use for cooking and heating will, in the immediate future, proceed at so great a rate that we can form no adequate conception of the ultimate demand that will be made on our gas factories. In these factories we now employ gaseous, in preference to solid, fuel wherewith to heat the retorts in which the gas coals are carbonized.

For developing power directly by the use of gas 22,000 gas engines of the "Otto" type have been sold. These, at an average of 4 horse-power each nominal, or 8 horse-power indicated, give a total of 176,000 indicated horse-power; and to this extent gas engines of this one type have supplanted the old-fashioned steam-boiler with its coal-furnace and atmosphere-polluting chimney-stalk, etc.

For general cooking purposes no fuel could be more constant and economical, and I refer you to the accompanying table in which are embodied the results obtained by various experimentalists. The great economy of gas at 3s. per 1,000 cubic feet over coals costing 16s. 6d. per ton is there illustrated.

is wanted from early morning till late at night, the kitchen-range should then be coal-fired.

The ordinary coal fire is a particularly wasteful one, as it is computed that only one-fifth of the heat that ought to be available from the coal to warm the room is effective, the other four-fifths passing up the chimney flue. When we did not use any other form of fire for warming the air of rooms than the ordinary open coal fire, it never occurred to us that any special means should be adopted for ventilating the apartment. Such a thing would seem to be quite superfluous when it is calculated that the enormous volume of 10,000 cubic feet of air is drawn up each ordinary fireplace every hour; and, as our atmosphere is much more frequently moist and cold than warm and dry, this cold damp air drawn hourly through each room must be one of the readiest means of producing colds and other ailments. In the future a very responsible duty will be placed on architects, who will be required to provide proper means to control the ingress and egress of air to each apartment (other than the rough-and-ready plan of the past—by yawning open fireplaces), and thus convey away the products of respiration and combustion at a level as near to the ceiling as possible.

To use gas economically for lighting purposes, we should employ as large flames and as few of them as possible, with not more than $\frac{7}{10}$ of an inch of pressure on the house fittings; for gas of 23 candle-power, $\frac{5}{10}$ of an inch of pressure would certainly be better if we could use so low a pressure with this rich gas, and at the same time prevent the flame from giving off smoke or unconsumed carbon. We sometimes hear of people complaining of not being able to read the newspapers in their rooms, while they have two or three jets all burning at one time. The reason for this state of things is that the burners are too small, whereby the consumer may be losing 60 per cent. of the light which the gas is capable of developing; and the remedy is to get one good Bray's adjustable burner, No. $\frac{8}{5}$ for large rooms, or No. $\frac{7}{4}$ for parlours and bedrooms, and a No. $\frac{5}{3}$ for small apartments, in place of using three or four smaller ones. By burning the gas in this way 50 per cent. to 100 per cent. more light from the volume of gas used will be obtained; and if a satisfactory light is not obtained by these burners, then there is some defect either of the fittings or of the supply requiring immediate attention. A good No. 7 or No. 8 Bray's regulator jet would also develop the light-giving qualities of the gas to advantage.

It should be borne in mind that the old-fashioned glass globe is not suited for these burners, any more than for the old pattern small jets, owing to the upward rush of air preventing the flame from attaining the high incandescence necessary to the development of light from the carbon; no globes should be used which have the lower opening smaller than the upper one. New globes of clear glass, with a 4-inch or 4½-inch opening, both at top and bottom, do very well.

It must be a very large room indeed when, except for effect or ornamentation, more than one burner is required to light it properly, so that even a newspaper may be comfortably read in any corner. One No. ⅝ or ¾ Bray's adjustable burner, consuming about 5 cubic feet per hour, will light a room 18 feet by 15 feet. I show here three Bray's No. 3 regulator jets, consuming 9 feet per hour, and more light is got from the No. ⅝ adjustable burner, consuming 5 feet per hour, than from these. To explain the loss arising from the use of small jets and too much pressure, I have prepared wall diagrams from the tables by Dr. William Wallace and Dr. Stevenson Macadam. These clearly show the loss from not properly developing the light-giving properties of the gas in *one* flame.

TABLE II.

TESTS WITH 25-CANDLE GAS.

Jet No.	Cubic Feet of Gas per Hour.	High-grades. H. Standard Sperm Candles.	Illuminating Power developed for every 5 Cubic Feet.	No. of Candle Hours for 1d for every 5 Cubic Feet [illegible] 25 Candle Gas at 4s. per 1000 Cubic Feet.	Percentage of Loss of Candle Hours.
					Per Cent.
5	5	25	25	93·33	0
4	4	20	20	80·6	7
3	3	15	25	76·66	18
2	2	[illegible]	19	65	30·25
1	1	8	15	50	46·5
0	0		10	33·33	64·5

¼" pressure.

Dr. S. MACADAM.

TABLE III.

Tests with 26-Candle Gas.

Jet.	At ·5 Inch Pressure.				Jet.	At 1 Inch Pressure.				Jet.	At 1·5 Inch Pressure.			
No.	Gas per Hour.	Illuminating Power.	Illuminating Power per 5 Cubic Feet.	Loss.	No.	Gas per Hour.	Illuminating Power.	Illuminating Power per 5 Cubic Feet.	Loss.	No.	Gas per Hour.	Illuminating Power.	Illuminating Power per 5 Cubic Feet.	Loss.
	Cub. Ft.	Candles.	Candles.	Per Cent.		Cub. Ft.	Candles.	Candles.	Per Cent.		Cub. Ft.	Candles.	Candles.	Per Cent.
8	5	26·0	26·0	0	8	Gas blows.	...	...	...	8	Gas blows.	...	...	...
7	4·75	24·76	26·0	0	7		...	...	...	7		...	...	...
6	4·1	19·6	23·90	8¼	6	5·7	25·60	22·46	13½	6	...	...	...	...
5	3·25	13·84	21·30	18¼	5	4·5	18·78	20·87	19¾	5	5·55	21·90	19·73	24
4	2·85	11·97	21·00	19½	4	4·05	15·44	19·06	26¾	4	5·0	16·62	16·62	36
3	2·35	8·98	19·10	26½	3	3·4	11·73	17·25	33½	3	4·3	13·67	15·9	39
2	1·7	4·85	14·27	45	2	2·5	6·74	13·48	48¼	2	3·1	7·62	12·3	53
1	1·45	3·77	13·00	50	1	2·15	5·28	12·28	52¾	1	2·85	5·47	9·6	63
0	1·15	1·96	8·52	70	0	1·55	2·35	7·6	72	0	1·8	2·45	6·8	74

Dr. Wallace.

It is well known that it is impossible to regulate the supply of gas to any town or city so that all consumers shall have a uniform pressure at the burner, and hence every house service should have a controlling governor to prevent undue pressure, for by far too few consumers pay any heed to the pressure of their house gasfittings. I have had a few tests with burners at what may be taken as representing the average pressure in house fittings—namely, somewhere in the neighbourhood of 1 inch—in order to ascertain what advantage, if any, would be got by introducing a burner that would, to a limited extent, take the place of the governor on the house supply service. The burners tested were Bray's "adjustable" and Sugg's "regulator," the quality of the gas having first been ascertained by the ordinary regulated jet. The "adjustable" burner consists of two separate tubes screwed together, so that a slight amount of longitudinal movement with either—the top or bottom portion—is possible. The result is what I assumed were sufficiently satisfactory, as will be seen from the diagram, tabulating the test experiments on the two. The value of the used by each, with the figures relating to the burner and maintained for five feet per hour.

[illegible]

This table shows the [illegible] more than better development [illegible] the gas [illegible] adjustable burner, even with [illegible] the gas consumption [illegible] regulator burner was [illegible] that for which used when [illegible]

[illegible] Question is that, [illegible] as compared with [illegible] Society [illegible] highly [illegible] [illegible] [illegible]

TABLE IV.

Tests with Bray's Burners, Seven-tenths Pressure.

"Adjustable."				"Regulator."			
23·37-Candle Gas.				24·32-Candle Gas.			
Nos.	Consumption of Gas per Hour. Cubic Feet.	Illuminating Power. Actual Candles.	Illuminating Power. Five Feet per Hour.	Nos.	Consumption of Gas per Hour. Cubic Feet.	Illuminating Power. Actual Candles.	Illuminating Power. Five Feet per Hour.
$\frac{8}{8}$	3·5	16·61	23·73	6	4·09	18·49	22·60
$\frac{7}{8}$	3·2	15·32	23·94				
$\frac{6}{8}$	3·2	15·47	24·17	5	3·42	14·29	20·80
$\frac{5}{8}$	3·0	13·62	22·70				
$\frac{4}{8}$	2·5	11·72	23·44	4	2·83	9·70	17·13
$\frac{3}{8}$	2·2	9·28	21·09				
$\frac{2}{8}$	2·1	9·44	22·47	3	2·45	7·00	14·08
$\frac{1}{8}$	2·2	8·72	19·81				
$\frac{4}{4}$	1·9	7·21	18·97	2	2·06	4·85	11·77
$\frac{3}{4}$	1·9	6·62	17·42				
$\frac{2}{4}$	1·7	6·45	18·94	1	1·77	3·54	10·00
$\frac{1}{4}$	1·6	5·13	16·03				
$\frac{0}{8}$	1·2	3·84	16·00	0	1·31	1·85	7·06

William Key.

Liverpool and Manchester, where the illuminating power of the gas is 20 candles, also Leeds and Carlisle, with 18 to 19 candle-power); yet we, representing only, say, two millions of Scotch consumers, who have always believed that they have been using gas of at least 26 candle-power, never discuss the "gas question" without the vitiation of the atmosphere becoming a leading topic.

We cannot expect anything else than that the uninitiated ordinary consumer should imagine that a richer quality of gas must be a better quality. From this misapprehension and a want of knowledge of the enormous loss he sustains by paying for a quality of gas which he is unable to use, unless in a manner whereby only a fraction of its illuminating power is developed at the burner, he is never heard to ask for a lower quality of gas, as his reasoning leads him to be afraid of increased gas accounts, loss of light, and a greater vitiation of the air of his rooms. It is a fallacy to suppose that gas manufacturers sell light—no such thing; if we did, then we ought to be bound to supply at the burner the full light-giving properties of the gas, be it 20 candle-power or 26 candle-power, developed in one flame, as it is manufactured to be used; but, unfortunately, we only sell "coal-gas," and the matter of the light to be developed from it at the burner is left entirely in the hands of the consumers. It is a pity that the elucidation of this subject is hindered year by year by a few gas manufacturers who support the popular outcry for still richer gas, whereas by virtue of their position they ought to be "men of light and leading," instead of talking as if they did not know any better than an ordinary consumer.

It is only by the methods prescribed by Act of Parliament, by the use of nicely adjusted and expensive appliances and governors, in the stillness of our dark gas-testing chambers, that the full light-giving properties of 26-candle gas can be economically developed; and the impossibility of applying to the burners of ordinary consumers the care practised by the gas examiner renders it impracticable to consume so rich a gas in a profitable manner in ordinary work-a-day practice.

Should the pressure be too low the air becomes filled with smut and smoke, and a stifling sensation is the result; even when the proper pressure is applied, should the least current of air disturb a flame of this sort, the result is the same; and when more than the proper pressure is applied so as to "stiffen" the flame, then there is vitiation of the air of the apartment from the escape of un-

consumed or improperly consumed gas. This is caused by the too rapid passage of the gas upward in the flame, which does not allow of sufficient time for the oxidation of the gas.

It is impossible by any means to get 26-candle gas practically applied to general illuminating purposes, if it is to be profitably consumed, so as to develop its full light-giving properties at the burner. To do otherwise, while entailing loss on the consumer, it has been proved (1) that 26 candle-power light at each burner was not wanted or required, but a light of less candle-power; and (2) that the percentage of loss, by reducing the volume of gas used below 5 cubic feet per hour at each jet, increased as the amount used became less; so that a point was reached in every-day practice entailing a serious tax on the poor. The generality of consumers, being the poorest class, are found paying 30 to 60 per cent. more for the gas they do burn than those who require more light and develop it at the burner accordingly. The manufacture of 26-candle gas was a serious tax on the poorer consumers, who seldom, if ever, desired it, and in fact did not require more light than from 10 to 12 candle-power at any one burner.

I have tested these two burners [shown], each consuming $2\frac{1}{2}$ feet per hour, and when placed so as to consume the five feet in one flame, and have found the loss, by dividing the five-feet flame into two, each consuming $2\frac{1}{2}$ feet per hour, to be $77\frac{1}{2}$ per cent. By the consuming of the five feet per hour in the single flame, the solid particles of carbon in the gas are highly heated with the assistance of the burning hydrogen gas, thus reflecting light and giving the flame its luminosity; so that the more heat we can get in one flame, the better light we get from the volume of gas burned; and on the other hand, the smaller the volume of gas burned in one flame, the loss of light from the volume actually used becomes greater. To explain this, let us assume the gas to be of 25 candle-power, with a consumption of 5 cubic feet per hour; then, when one-fifth of the gas is used—namely, one foot per hour,—one-fifth of the 25 candle-power, or 5 candle-power light, is not evolved, but one-and-three-quarters candle-power. Thus, when 25 candle-power gas is so used, only 8·75 candle-power is obtained for every five feet used, in place of 25 candle-power, being a loss to the consumer of 65 per cent.

I have made a calculation in order approximately to discover what loss accrues to the Glasgow public by the use of 26-candle gas in their dwellings, and I take for my purpose the district

within the city boundaries. In making up my estimate of loss, I have used the tables prepared by Dr. William Wallace, the City of Glasgow Gas Examiner. When I mention lights of 20 candle-power, I assume that 20 candle-power is the maximum light developed at the burner for every five feet of 26-candle gas used in one light per hour, in daily practice; and the percentage of loss with lower qualities of gas will be found to be in the same ratio, according as the burner used be large or small. In examining the accompanying table, it is not necessary that the exact number of lights and quantities of gas used be obtained; it is sufficient if we have a table approximately correct, for it would be quite impossible to obtain by a house-to-house visitation any more reliable data.

(See Table on page 97.)

The important feature of Table V. is that it works out a given volume of gas used, when anything larger than a 10 to 12 candle-power light would be an utter waste of light, and shows the loss to those consumers by their developing only 10 to 12 candle-power light, while using 26 candle-power gas to do so.

In the first column we have shown the number of rooms in each house; and the second column shows the number of houses within the city having these numbers of rooms in each, for the year 1881. This information I obtained from Mr. Nicol, the City Chamberlain. In the third column is shown what I estimate may be the annual gas account in each of these houses, in cubic feet of gas, up to houses of seven apartments; and the fourth column shows the money value at 3s. per 1,000 cubic feet. The probable total number of lights in each house is given in the fifth column, and the next shows what number of these are likely to be of 10 to 12 candle-power. In the seventh column we have the number of houses multiplied by the number of 10 to 12 candle-power lights, showing a total of 255,177 lights. The eighth column represents the number of lights in each house, that may reasonably be expected to develop 20 candle-power at the burner. Of course, although we assume that these lights develop this rich quality of gas at the burner, we may fairly estimate that not more than one-tenth of these do actually develop anything like 20 candle-power, and that 16 to 18 candle-power would probably be nearer the mark. However, we say in the ninth column that 54,310 jets are represented to be of 20 candle-power. This number is equal to one-sixth of the total lights of all kinds in the houses within the city. In column ten, we have the total volume of gas

TABLE V.

Estimated Loss in Money Value per Annum to Glasgow Consumers, while using 26-Candle Gas.

No. of Houses in the City in 1881.		Probable Annual Gas Accounts.				Probable No. of Lights.		No. of Houses multiplied by the No. of 10 to 12 Candle Power Lights in each.	No. of Lights in each House of 20 Candle Power.	No. of Houses multiplied by the No. of 20 Candle Power Jets in each.	Annual Consumpt in Cubic Feet by Light of 10 to 12 Candle Power in each House	Annual Consumpt by each Jet of 10 to 12 Candle Power in Large Houses.	Cubic feet of Gas used annually by Lights of 10 to 12 Candle Power in the dwellings of—	
No. of Rooms.	No. of Houses.	In Cubic Feet.	At 3s. per 1000 Cubic Feet.			In each Dwelling House.	Of 10 to 12 Candle Power.						Small Consumers.	Large Consumers.
			£	s.	d.									
1	40,820	2,500	0	7	6	1	1	40,820	...	...	2,500	...	102,050,000	...
2	47,029	4,000	0	12	0	2	2	94,058	...	...	4,000	...	188,116,000	...
3	15,482	7,700	1	3	1	4	3	46,446	1	15,482	5,700	...	88,247,000	...
4	5,852	14,000	2	2	0	5	4	23,408	1	5,852	12,000	...	70,224,000	...
5	1,883	23,000	3	9	0	7	5	9,415	2	3,766	19,000	...	35,777,000	...
6	1,390	30,000	4	10	0	8	6	8,340	2	2,780	24,000	...	33,360,000	...
7	604	40,000	6	0	0	11	7	4,228	4	2,416	28,000	...	16,912,000	...
8	348	...		...		15	8	2,784	7	2,428	...	4,000	...	11,136,000
9	260	...		...		16	9	2,340	7	1,820	...	4,000	...	9,360,000
10	262	...		...		20	6	1,572	14	3,668	...	4,000	...	6,288,000
11-15	578	...		...		25	11	6,358	14	8,092	...	4,000	...	25,432,000
16-20	150	...		...		45	16	2,400	29	4,350	...	4,000	...	9,600,000
21-25	35	...		...		52	22	770	30	1,052	...	4,000	...	3,080,000
26-30	17	...		...		70	30	510	40	680	...	4,000	...	2,040,000
31	48	...		...		76	36	1,728	40	1,906	...	4,000	...	6,912,000
	114,758							255,177		54,310			534,686,000	73,848,000
													73,848,000	
													608,534,000	
													30%	
												100	18,256,020	
													3/	
												20	547,680	
													£27,384	

William Key.

used annually by lights of 10 to 12 candle-power. That is got by deducting from column three the volume of gas used by each 20 candle-power light. Then, in the next column we have computed that in the larger houses 4,000 cubic feet are used annually in each jet of 10 to 12 candle-power. And to find the total quantities of gas used by the 10 to 12 candle-power lights, we multiply the number of houses by the quantities of gas used by the lesser houses for the smaller lights per annum; and for the larger houses, multiply the number of 10 to 12 candle-power lights by the 4,000 cubic feet to each.

The result is that we get a total of 534,687,000 cubic feet as having been used in this district by the smaller consumers, and 73,848,000 cubic feet as used in the smaller lights by the large consumers. These quantities together give a total of 608,534,000 cubic feet, and of this total the larger consumers are only represented to have misused by their small lights about one-eighth of the whole. Then the loss incurred by putting the 26 candle-power gas to use in only developing 10 to 12 candle-power at the burner, and by defective burners and excess of pressure, I estimate at not less than 30 per cent. of the light-giving properties of the gas.

This percentage shows a loss per annum, on this district house supply alone, of a value of £27,384. But there has been sold three and a half times more gas than is represented by these figures, and we may reasonably assume that in the suburban districts there are fewer small houses in proportion to the large; and in place of only one-sixth of the lights being properly developed, we may say that one-third of the whole of the remainder of the gas sold, whether for houses or places of business, is fairly well consumed at the burner. Of the remaining two-thirds I am quite sure it will be found utterly unnecessary to have, in the position where these lights may be, any more than 10 to 12 candle-power in one flame. Two-thirds of the remaining gas sold per annum amount to a volume of 1,014,222,000 cubic feet, and on this quantity I again allow a loss to these consumers of 30 per cent., which, at 3s. per 1,000 cubic feet, is equivalent to an additional loss of £45,689; this sum, with the £27,384 already mentioned, gives a total of £73,073 of an annual loss. By the figures given by Mr. Nicol there were within the city in the year 1881, 114,758 dwellings, and allowing the increase since to go for those houses in which no gas is at present used, I have dealt with the former number as if gas were used in each house. I have estimated that of the total 309,487 lights

only 55,000 exist where, from the nature of the dwelling and size of rooms, we may reasonably desire to see 20 candle-power developed at the burner; that is to say, 5 cubic feet would be consumed in each jet per hour, when we might then say these lights were developing the full light-giving power of the gas, and little waste could be said to be going on. It is very different with the 255,000 jets using only, say, three feet per hour. The loss of light from the gas actually used is represented to be equal to the consumers paying 30 per cent. more for their gas than those more fortunately placed 55,000 jets of the larger consumers, who obtain full value in light from the gas for their money.

The waste and loss experienced rest almost entirely with the mass of consumers; or, in other words, the mass of consumers, being those who are less able to bear the loss, are greater wasters and losers, by using or misusing the rich gas, than those consumers who are better able to burn their gas in a large flame properly. It is thus proved that the mass of consumers should be supplied with a very much cheaper gas, to enable them to consume more of it in each burner, and so economically and properly develop the full light-giving power of the gas at their burners. This would lead us to recommend for them 18 candle-power gas, 16-candle gas being the average quality used in England and Ireland, where there are twenty times more gas consumers than there are in all Scotland. The working-classes, from being unable to use or require a light of 20 candle-power in one burner, pay a price by the use of their small jets that helps to make them think gaslight dear, and were they further to reduce the amount used at each burner—with the view of saving,—such a course would only add still further to their loss.

Again, 26 candle-power gas is quite unfitted to stand the rigorous test of severe winter weather, for when coal-gas is manufactured above 18 or 20 candle-power, as the quality increases the depreciation caused by exposure to frost becomes greater; so that the sensible way to decide what quality of gas to manufacture would be to consider what quality would be the least costly to maintain at that standard during keen frosty weather in winter. The endeavour to maintain the quality of Glasgow gas at 26 candle-power in the gasholders in midwinter costs each manufacturing station a sum reaching from £50 to £80 daily, for extra quality of first-class coals, as compared with the production of gas of the same quality from a less costly coal on a mild winter day when there is no frost. This sum multiplied by

three for each of the manufacturing stations per day (often for months together), and added to the loss already described, will give an average total loss of, say, £100,000 per annum.

Before closing my remarks on this subject, let me say that we may safely assume that there are throughout the world 100 millions of gas consumers, who are using at the present time an average quality of gas of 16 candle-power, and that they are assured of a supply of coal capable of giving them this quality of gas (equal to what they have always used in the past) for thousands of years to come; whereas the Scotch consumers, representing only, say, two millions, are not assured of first-class coal supplies and a continuance of 26 candle-power gas for ten years. I may also safely say that the entire gas consumers of the world, with the exception only of Scotland, at the present time use a quality of gas from 14 to 16 candle-power. Those persons who object to Scotland "doing likewise" must in their reasoning show how the consumers of that quality of gas, by using more of it, have a higher death-rate from vitiation of the air of rooms, or are otherwise enfeebled, or if their light per candle-power is to them more expensive than if they used gas of 26 candle-power. The gas manufacturers of all Continental Europe, of America, the British Colonies, England, and Ireland, should not only be shown to what extent they are wrong in manufacturing 16 candle-power gas, but be directed to where the supplies of material wherewith they might manufacture rich gas above 18 or 20 candle-power are to come from, and say whether the whole gas world could be so supplied for an entire year. If 26-candle gas is good for Scotland it must be as imperative that they also should manufacture gas of that quality. It is useless, however, to argue in this strain, for were they to adopt 26 candle-power the price would be increased many-fold, and the supply could not be maintained even for a single year.

It seems unpatriotic to insist that only Scotland should be debarred from sharing in the advantages of obtaining cheap gas, which would be developed by using more of it. Four feet per hour for the generality of consumers would be found sufficient to give them the light they required, and never more than five feet per hour would be used in any burner at one time. It would be cheaper to thus develop the full light-giving properties of the 18-candle cheap gas at the burner than by only developing, as at present, 10 to 12 candle-power with 26-candle gas.

By studying what quality is best for the mass of consumers, so as to give them a cheap light, the use of coal-gas would be rendered more popular, and other means of illumination (*e.g.*, by paraffin lamps) would be discarded as troublesome by requiring to be trimmed, fountains refilled, and risks of breakages would be avoided, and a pure lower-quality gas would be more pleasant and wholesome than stinking oil lamps or candles.

We are thus placed face to face with the inevitable, and must at last recognise the fact that nature cannot alter. We will profit by paying some heed to the instruction which a study of the subject gives us while we can do so calmly, so that we may not be caught unawares and suddenly be forced to alter all our calculations and modes of manufacture and consumption of coal-gas.

IX.—*Notes on the Bursting of Leaden Service Pipes by Water and Frost.* By GEORGE C. THOMSON, F.C.S., President, Graduates' Section, Institution of Engineers and Shipbuilders in Scotland.

[Read before the Society, 5th January, 1887.]

SOME three or four winters ago my friend Mr. J. L. Bruce, Architect, drew my attention to a burst water pipe, and especially the manner of its bursting; later on he mentioned that on questioning plumbers and others as to the cause and time of pipes bursting during frost, he found the general impression to be that the pipe only burst after a thaw had set in, and was caused by the ice in the pipe melting, and the pressure thus becoming too great for the strength of the metal.

In order to refute this idea he collected a large number of burst pipes, a few samples of which you see on the table before you. Owing to various causes the subject remained in abeyance till lately, when he suggested that I should take up the matter, and lay it before you, as he was unable to do so, in consequence of having to go abroad for his health.

Before proceeding to give some of the results of the inquiry, it may be desirable to mention a few preliminary considerations in reference both to water itself and to lead. The first-named body exists in three forms—as solid, fluid, and vapour,—but at present we will only consider it in the fluid and the solid forms. Pure water freezes, or changes into the solid form known as ice, at 0° C., or 32° Fahr., but it possesses the property of remaining liquid at a temperature as low as – 24° C., provided that it be kept still, and that sufficient pressure is maintained to prevent its expansion. Boussingault (*Compt. Rendu*, lxxiii., p. 78) observed that water enclosed at 4° C. in a cast-steel tube, thick enough to

be regarded as inextensible, remained liquid for several days at − 24° C., as shown by the mobility of a steel ball enclosed in the tube. Solidification took place on opening the tube and allowing the water to expand. Further, Martins and Chancel (*Ann. Chem. Phys.* (4), xxvi., p. 560) examined the phenomena attending the bursting of shells by the freezing of water. They found that no matter how low the temperature of the air, the temperature of the enclosed water at the moment of splitting the shell (there was no scattering of fragments) never sank below − 4·2° C. The proportion of water frozen varied from 20 to 30 per cent., and the pressure exerted thereby was sufficient to reduce the entire volume by $\frac{1}{45}$ to $\frac{1}{85}$. Water reaches its greatest density at a temperature of 4° C., or 39·2° Fahr., and expands with the decrease and increase of the temperature from this point. Water in the act of freezing expands by fully 10 per cent., as a volume of ice at 0° C. gives 0·908 volume of water; or 1 volume of water at 0° C. gives 1·102 volumes of ice. The density of ice at 0° C. is 0·9175—water being taken as unity.

The compressibility of water is very slight, one atmosphere (15 lbs. pressure) reducing its volume to the extent of 0·000045 (Oersted), or 0·000047 (Regnault), while, on the authority of Perkins, its volume is said to be reduced to the extent of $\frac{1}{12}$ by a pressure of 200 atmospheres, or 3,000 lbs. per square inch. The addition of 5 per cent. common salt diminishes the compressibility 0·0000419, 15 per cent. 0·0000356, and 30 per cent. 0·0000306.

I shall now touch upon the next substance under consideration, viz.:—Lead.

Of the lead used in commerce the English is the purest, and the Spanish the most impure. The composition in 100 parts is generally as follows:—

	English.	Spanish.
Lead, ...	99·27	95·81
Antimony, ...	0·57	3·66
Copper, ...	0·12	0·32
Iron, ...	0·04	0·21

Even the English sample is so impure that it might be called a *hard lead.*

The presence of impurities affects the ductility and malleability very much. Common impurities are—oxide of lead, which is dissolved in small quantities while in a melted state; zinc, tin, antimony, &c. Lead has a very low tenacity. The tensile strength

of lead is variously estimated at from 1,400 lbs. per square inch by Trautwine, and by other authorities, as below :—

Cast lead,	1,930	lbs.	per square inch,	by D. K. Clark.
Sheet, ,,	2,040	,,	,,	,,
Pipes ,,	2,240	,,	,,	,,
,, ,,	2,745	,,	,,	Box.
,, ,,	3,300	,,	,,	Rankine.
,, ,,	2,159	,,	,,	Kirkaldy.

Impurities or small quantities of other metals reduce the specific gravity, and have the tendency to make the lead harder, while increasing the tensile strength generally, which, in pipes, is rather an advantage than otherwise, if not carried to excess.

The pipe in the Royalty Theatre which set this inquiry on foot was led in from the street, taking a sharp turn inside the wall, and being carried through a cellar which was not heated in any way. It was led up past an open window fitted with louvre boards, and a few feet through the floor above, where it terminated with an ordinary tap. A column of ice was formed in the pipe, and owing to the bend it could not move; it practically formed a plug, so that the water in the pipe higher up was under considerable pressure, increasing as the congelation continued in the pipe, until the pressure became so great that the strength of the metal was overcome. At the moment of release, by the pipe giving way, the remaining quantity of water immediately froze, and until the temperature rose above the freezing point it gave no inconvenience, as regards flooding the premises. Considering the facts regarding water previously mentioned, this is just what we should expect; for it is self-evident that if we take a pipe, fill it with water at its greatest density, securely plug up the ends, and place the two ends of the pipe in a freezing mixture, so that ice is formed, then as the formation of ice proceeds from each end the water in the middle increases in pressure, with the result that the pipe, if of lead, is bulged out in the centre, and ultimately bursts.

The question naturally arises:—At what pressure do these pipes burst? In trying to answer this question I found it was of no use to calculate from the tensile strength of lead, as no two authorities gave the same figures, varying as they do from 1,400 lbs. to 3,300 lbs. per square inch. Such a variance is, no doubt, caused by the presence of impurities in the samples tested. I expected that the Rules of the Glasgow Corporation Water-works

would prescribe that the lead service pipes should have a certain limit of strength as a minimum, but on looking up these Rules, I only found that certain weights per yard were mentioned, and that neither strength nor quality was specified. "*Rule 8.*—All service pipes, unless otherwise specially agreed upon, shall be of lead, and of the following weights per yard :—

½-inch diameter, 7 lbs. per lin. yard.
¾-inch diameter, 10 lbs. per lin. yard.
1-inch diameter, 14 lbs. per lin. yard.
1¼-inch diameter, 18 lbs. per lin. yard.
1½-inch diameter, 24 lbs. per lin. yard.

Overflow pipes may be of lighter weights."

In order to have some idea of the strength of these pipes, I had a piece of each size burst by water pressure, and the particulars you will find in the first part of the accompanying Table:—

G. C. W. W.—STANDARD LEAD PIPES.

Dia. of Pipes.	Thickness of Pipe.	Weight in lbs. per yard	Bursting pressure per sq. in.	Weight per cub. in.	Ratios.	Tensile strength per sq. in.	Specific Gravity.	Weights for equal strength
½ in.	·20	7 lbs.	1,820 lbs.	·396	167	2,275·0 lbs.	11·00	4·2
¾ ,,	·23	10 ,,	1,232 ,,	·398	112	2,008·7 ,,	11·08	8·9
1 ,,	·24	14 ,,	1,091 ,,	·400	100	2,272·9 ,,	11·124	14·0
1¼ ,,	·26	18 ,,	1,036 ,,	·397	95	2,490·4 ,,	11·03	18·9
1½ ,,	·29	24 ,,	812 ,,	·404	74	2,100·0 ,,	11·24	32·4
The Tensile Strength was 2,229·4 lbs. per sq. in.								

Bruce & Thomson.

KIRKALDY'S EXPERIMENTS ON LEAD PIPES.

				*	*	*	
½ ,,	·2	6·9	1,579 lbs.	·434	173·3	1,973·7 ,,	
⅝ ,,	·2	7·9	1,349 ,,	·418	148·	2,107·7 ,,	
¾ ,,	·22	11·4	1,191 ,,	·472	130·7	2,030· ,,	
1 ,,	·2	12·3	911 ,,	·452	100·	2,277·7 ,,	
1¼ ,,	·21	15·9	683 ,,	·459	74·9	2,032·6 ,,	
1½ ,,	·24	21·3	734 ,,	·461	80·5	2,293·7 ,,	
2 ,,	·21	27·6	498 ,,	·526	54·6	2,371·4 ,,	
The Tensile Strength was 2,159 lbs. per sq. in.							

* Calculated from the first 4 columns.

We would naturally suppose that the strength of these pipes would be on an equality, or nearly so, but you will see from the Table that this is very far from being the case, the ½-inch pipe bursting at more than double the pressure that the 1½-inch pipe bursts at. On referring to the column of specific gravity, you will see that the ½-inch pipe is the lightest, and would contain the most impurities, while the 1½-inch pipe is the heaviest and purest. Of the impurities generally present in lead pipes—

Tin has a tensile strength = 4,736 lbs., Rennie.
Zinc, ,, ,, = 2,993 ,, Stoney.
Soft Solder (2 tin, 1 lead), = 7,500 ,, Rankine.

If the 1¼-inch pipe is impure lead, as its specific gravity would seem to show, this would account for its greater strength. Mr. Jardine found that 1½-inch pipe ⅛-inch thick stood 1,000 feet head of water without alteration; at 1,200 feet head it began to swell; enlarged to 1¾-inch diameter at 1,400 feet head it burst—giving a bursting pressure of 606 lbs., or 2,611 lbs. tensile strength; 2-inch pipe ⅛-inch thick stood 800 feet head without alteration; at 1,000 feet head it burst—giving 433·5 lbs. bursting pressure, or 2,412 lbs. tensile strength. Thus—

1½-inch pipe remained unchanged up to 0·71 of bursting strain.
2-inch ,, ,, 0·75 ,,

I have no idea why the Glasgow Corporation Water-works Rules specify the weights mentioned, as you will see from the last column that for equal strength the small pipes should be lighter and the larger pipes heavier than are specified. You will see the difference plainly from the samples of ½-inch pipes on the table, which have the weights per yard stamped on each sample. If you take a look at the results shown in Mr. Kirkaldy's experiments, which are given in the second portion of the Table, you will notice that all the pipes were practically of the same thickness; and you will also notice that the tensile strength agrees pretty closely with that of the Glasgow pipes, as found by my experiments. Box, in his "Strength of Materials," gives the safe working pressure, without any shocks, at $\frac{1}{10}$ of the working pressure, and with shocks, at $\frac{1}{20}$ of the strain. Trautwine, taking the ultimate strength of lead pipes at 1,400 lbs. per square inch, gives a factor of safety of 6 when the pressures are quiet; but this is not enough when shocks take place, such as are caused by the sudden closing of a tap. This produces the well known knocking or hammering sound which is heard in that case, and which is

scarcely avoidable in the ordinary water supply service of towns. These shocks can be avoided when a screw-down tap or a ball cock is used, which closes gradually. It may be the case that this is the reason why the smaller pipes are made so much stronger in proportion, but it would not hold good in the case of a number of small pipes and short lengths taken from a large pipe. In this case the large pipe would be too weak to stand the repetition of a sudden shock of two or three taps being closed suddenly at the same time. Another reason for the smaller pipes being so much heavier may be on account of the numerous bends to which they are subjected when being fitted up in houses, and which, in the case of the larger sizes, are not of so frequent occurrence. I should like to draw your attention to the pieces of pipe which are sawn through at the burst part, and notice an instance of the flow of metals under pressure. The pipes burst by water pressure, without the intervention of frost, have a break, showing a long, narrow slit, just sufficient to ease off the pressure, while those burst by the action of frost have the lips of the pipe at the burst part forced out to varying widths, as seen in the examples submitted. This is caused by the solid ice being forced out by the expansion of the water at the moment of freezing. The character of the break might be used as a test for the quality of the metal of which the pipe is made.

The question might be asked as to what length of pipe would require to be frozen to produce sufficient pressure to burst the pipe. In this sample [piece of $\frac{3}{4}$-inch pipe shown by author], it would require a length of about 7 inches to produce the burst by the expansion of the water in the act of freezing. This would only be sufficient to burst the pipe, but would not force it open to the extent you see, which is caused by a far greater length of pipe. The surplus water freezing at the instant of release, and being forced out in the act of expansion, would form a solid lump of ice on the outside of the pipe, not a drop of water being lost in the process of changing form.

I daresay you have all seen this for yourselves when a pipe, cylinder, or other vessel has been burst by the frost, and the ice projecting out several inches from the surface. This is another instance of the flow of solid bodies, and is to be seen in perfection among the Alpine glaciers, where the molecules give way and accommodate themselves to the ground which they pass over.

X.—*Geographical Alto-Relievo Models, and their place in Education.* By WILLIAM MARTIN.

[Read before the Society, 2nd February, 1887.]

HAVING been invited by your committee to bring before you to-night the subject of Geographical Alto-Relievo Models and their place in Education, I shall first ask your attention to the measure of acquirement in Geography at present fixed in scholastic circles by the term Education, and to the aids hitherto available to teacher and scholar; and shall then show how the Alto-Relievo Geographical Model, as one of the latest educational appliances, is calculated to aid both teacher and scholar in more surely attaining that standard, and in preparing for further advances in the study.

First, then, the measure of geographical acquirement included in the term Education must be sought for in the schools of our country. These are of two great orders—the Private Academies, and the Public Board Schools. From the Private Academies we obtain no fixed criterion to guide us in our present estimate. In them each teacher fixes the standard of attainment himself, and we may say, all depends upon him. If he be a thorough educationist, the very absence of those periodic inspections upon which financial grants depend leaves him large opportunities, uncurtailed by the necessity of grinding and cramming; permitting on the one hand possibilities of special methods for bringing up the inevitable rear ranks, and, on the other, of pushing on attentive scholars far beyond the narrow limits of mere mediocrity. Yet with all their advantages, and, it must be admitted, with their disadvantages, the Private Academies do not furnish us with the measuring rod which we desiderate.

In the curriculum of the Public Board Schools, however, we find that criterion, and we find it fixed by the unchallenged authority of the Government Committee of Council on Education. It is reasonable that we should here accept that standard, because in these Public Board Schools 85 per cent. of the youth of our country are educated. The Government grant for education is so important

a factor in public school enterprise, that the official circular which the Committee of Council on Education annually issues to the School Inspectors, for their guidance in school examinations, is at once accepted by School Boards and by Teachers as the measure of the amount of information which scholars are required to possess in order to earn the grant.

The Government circular to School Inspectors states, *inter alia*:— "Instruction in geography, history, and elementary science will be given by means of books, oral lessons, and visible illustrations. . . . Geographical instruction is sometimes too much restricted to the pointing out of places on the map, and to the enumeration of such details as the names of rivers, towns, capes, and political divisions. Geography, if well taught, will include some description of the physical aspects of the countries." (Blue Book, 1885-6, pp. 100, 101.)

The schedules issued with that circular give tables of class subjects to be taken by the scholars of different years, or, as they are termed in school phrase, Standards. In regard to geography, the following is the curriculum :—

Standard III. (Age, 9-10).—Knowledge of Geographical Terms, and the outline of the Geography of Scotland.

Standard IV. (Age, 10-11).—The Geography of the British Isles.

Standard V. (Age, 11-12).—The Geography of Europe, with North America, and Australasia.

Standard VI. (Age, 12-13).—The Geography of the World generally, and specially of the British Colonies and Dependencies. Interchange of Products. Circumstances which determine Climate.

And in addition to these *Class Subjects*, there are certain *Specific Subjects* indicated for Standards IV., V., VI., such as Mathematics, Classics, Botany, Physical Geography. In the last-named the curriculum is as follows :—

1st Stage.—The nature of a river or stream, whence it is supplied, and what becomes of it. An explanation of the terms "river-basin" and "water-shed." The river-basins of Scotland.

2nd Stage.—The ocean, its extent and divisions, depth, saltness, currents.

Such is the Geographical Curriculum. It begins with the Geographical Terms at Standard III. The Government decide that Standard III. should be passed by scholars of 10 years; the Scotch Education Department have, however, fixed it for 9 years; we may therefore accept it that geography begins at 9 years of age, with the Geographical Terms, and an outline of Scotland.

To aid teachers and scholars in preparing to face the inspector in this subject, there have hitherto been in use the Geographical Primer or Text-Book and the Map. We need not describe these. The enterprise of scores of competing publishers and editors has multiplied books and maps to a bewildering extent, each with its own specialty—many of them of remarkable excellence.

Now, it will enable us more accurately to ascertain whether there be a place for a new educational appliance, such as the Alto-Relievo Model, and if so, what that place is, if we examine briefly the fitness of the present text-books and maps to meet unaided the requirements of school work. Naturally, therefore, we turn to the official reports of the Government Inspectors. There we find it the subject of repeated remark, that masters are too apt to rely upon mere text-book learning, so that school teaching partakes more of what is called "*cramming*," than of what is meant by education. What Butler preached 150 years ago is too much forgotten—"Of education, *information itself* is really the least part." Thus Dr. Wilson, one of her Majesty's three Chief Inspectors for Scotland, says in his last report:—"It still appears that these subjects receive a decided preference which can be got up with the least expenditure of time and trouble, and by the *aid of a manual*, with but little independent illustration on the part of the teacher." Mr. Harvie, another Inspector, writes in his last report:—"The contents of little text-books, which are crammed into the heads of the pupils, vanish from their memories like snow before a thaw, whenever they leave school." Mr. Marshall, another Inspector, in a previous report remarked:—"Experience generally proves that geography is weaker than history, and it is not difficult to find the reason. Geography is a wider subject, and cannot, like history, be limited to any text-book. Broadly, the map of the prescribed field is the limit, but within its compass there is great variety."

A corrective of this text-book grind would be a more frequent use of the map—the other aid available. But here Mr. Boyd, another Inspector, complains "that the map is too little used in

schools." Thus, again, Mr. Marshall says:—"History and geography make severe demands on the method and intelligence of the teacher. The chronological method alone seems to obtain in history, and the topographical alone in geography. The map has to give way to the text-book, which is frequently a mere skeleton, without flesh and blood."

The necessity of such strictures may be exemplified by a question we heard lately put by a teacher to a class—"Mention the stations between Leuchars Junction and Dundee." Such work, as far as geography is concerned, is mere topographical cram, and, as far as education is concerned, it is sheer scholastic sham. Now, why should true geography be thus allowed to fall into the background? Here we have a subject of study most interesting, indeed truly captivating. In our schools we have teachers able and earnest, and with no predilection to mere memory exercises; and in these public schools we have 600,000 scholars, from among whom will emerge our future merchants and shippers. That being so, why should this inadequate state of geographical tuition continue to exist in a country whose relationships, through commerce, emigration, and missionary enterprise, touch every corner of the wide world?

It is satisfactory, however, to know that progress is being made. The new Code of geographical tuition is in advance of the old, and under that new Code all schools are this year being examined. Perhaps the most important feature in it is the place given to Physical Geography. Formerly geography, as laid down in the requirements of the old Code, was completely divorced from physical geography. The new Code requirements in geography will certainly call more upon the thinking faculty by enforcing the forming of true notions of the typical shapes of land and water, and clear ideas of the build of the continents, and the features of a country. And it is precisely here that the Geographical Alto-Relievo Model of continent or of country, or of the typical geographical forms, has its place in education in the school. It is the complement of the text-book and of the map. It gives life and spirit to what hitherto has been "flat, stale, and unprofitable."

The educational effectiveness of Alto-Relievo Models has long been recognised and admitted. There is probably not a museum, however obscure, which has not some model—it may be of Jerusalem or Palestine, or of its own neighbourhood. But such models have hitherto been either too unwieldy and heavy for

school work, or too fragile, and always too expensive. Nevertheless, with what sudden ecstasy does the eye of any youthful visitor to a museum wander over the mountains and valleys of such a model, say, of Jerusalem, or Mont Blanc—yes, even the old and experienced eye of some *savant*, it may be a F.R.G.S.! That one survey through the dim, perhaps dusty, glass case in the museum has translated the spectator at once to the sunny slopes of Mount Olivet, or to the weird desolations of the Mer de Glace, and he knows the place ever afterwards with almost the familiarity of a native;—he can say, "I have seen it." How forcibly all this applies to children we may readily estimate by thinking of the intense passion of a child for a toy in preference to a picture. What to him is a Landseer's dog or a Rosa Bonheur's bull, in comparison to some rude four-footed bit of wood? Thus, the girl with her doll, and the boy with his box of bricks or his hurley-cart, seem to appeal to their teachers to see that when school-life banishes the familiar and cherished playthings of infancy, the school should march in the line of such natural appetites (which always indicate psychological laws), and provide something of the concrete to interpret or illustrate the abstract. This desire to see and handle a thing, instead of being satisfied with the mere description or picture of it, is not confined to children, but characterizes us through life. Who is there who has not profited by a visit to the Tower of London?—for though he may frequently have read of the knights encased in chain and plate armour, and though he may often have studied the pictures in our history books, yet the sight of these horsemen, even in motionless model, was a new revelation.

In the absence formerly of geographical models suitable for schools, teachers who recognized this power had to resort to expedients of one kind and another. One enthusiast, for instance, set his boys to dig up the earthy playground of his country school into the model of the valley of the river which ran through the village. But this method of demonstration is not always available.

Another teacher, in the classic region of Edinburgh, says, "take the scholar out and show him the Pentlands!" We hope we offend neither the *amour propre* nor the *amor patriæ* of this enthusiast for the Pentlands when we say that much will remain to be done even after that. Are all mountains like the Pentlands? What is the other side like? What is further on? Is all geography comprehended in showing the Pentlands?

Thus, we can now estimate the place of alto-relievo in geographical instruction. The Alto-Relievo Model presents to our eye, and to our very touch, the mountain ranges in their graded elevations, the water-sheds, the corresponding slopes, the general trend of the land, the course of the great continental rivers, and the causes which determine the direction of their flow; the oceans, seas, channels, gulfs, and bays lying in mirrored smoothness around the land; and it presents all in such vivid naturalness that the first view may be compared to the seeing of the continent at a glance, if that were possible.

I now pass round for your inspection models of the Continents, and of the Countries of Europe. Here is *all the World in Alto-Relievo.*

The Continents in Alto-Relievo are for the V. and VI. Standards.

The IV. Standard studies the British Isles, and the III. Standard is introduced to Scotland.

I have pleasure in now exhibiting for the first time, the newest work of my firm—Scotland in Alto-Relievo. The model is executed to the order of the School Boards of Edinburgh, Glasgow, &c. Such a model has long been a desideratum in schools. Mr. Dunn, one of the Inspectors, remarks in his last report:—"It is to be regretted that embossed maps of Scotland are not in use. Such maps, constantly used, I believe, in Germany, give a bird's-eye view of a country, render the courses of rivers easily explicable, explain the direction of canals, and to an appreciable extent of railways, form an introduction to the study of physical geography, and give a vividness and sense of reality to the geographical features of a country, which fix the facts upon the mind with impressive force."

Allusion has already been made to the stimulus which geographical study may be expected to derive from the introduction of an appreciable amount of physical geography in the requirements of the new Code. And it is pleasing to find this introduced at so early a stage as the Third Standard, in which part of the geographical course is a "Knowledge of the Geographical Terms." This study is begun about nine years of age—a time of life when the abstract is not so readily appreciated as the concrete. When we consider, therefore, the abstract nature of geographical terms, we can at once perceive the utility, nay the necessity, of embodying these geographical terms in solid

alto-relievo forms. The picture of an island is better than a mere verbal description, but the model of an island—what a child would accept as a real island—is assuredly best. So with the other geographical terms—peninsula, gulf, bay, mountain range, river, valley, &c.

The solid Alto-Relievo Model of the Geographical Forms and Physical Features, which I now exhibit, has been produced within the past few months, by my firm, to meet this want, and to simplify the attainment of the requirements of the new Code by the Third and Upper Standards in school; and it has received the hearty approval of the leading teachers in the city and elsewhere.

For the Third Standard, which is taught in large classes, any model must be large, strong, and portable. But these are three characteristics which it is exceedingly difficult to combine in one model, when at the same time the ratepayers' candidate insists upon yet a fourth and formidable characteristic—his *sine quâ non* —cheapness. This model of the Geographical Forms is the largest yet produced for school purposes, and it combines in a remarkable degree all the characteristics required.

I. It is large—$3\frac{3}{4}$ ft. × 3 ft. = $11\frac{1}{4}$ sq. ft. superficies.

II. It is strong in material, and in frame-work.

III. It is portable, being of convenient size and weight for a teacher carrying from one class-room to another.

IV. It has other merits. It is artistic in general appearance. It is full and exhaustive of school geographical nomenclature. It is true to nature, being not a mere mechanical assemblage of examples of geographical terms, but an ideal developed upon physiographic principles. To have given representations of actual portions of the world as illustrations of the terms (as, for example, Denmark or Italy for peninsula, Borneo or New Zealand for island), would have been to confuse geography in the scholar's mind by the juxtaposition in the one model of localities widely separated in nature. To have done so would have been to produce an unconnected and incoherent mass of examples, instead of a model containing in natural order and place instructive examples of all the terms of school geographical nomenclature.

Nor does the usefulness of this model cease with the Third Standard. There is much in it fitted for the higher stages of geographical instruction—such as illustrations of the table-land and plateau, river-basin, water-shed, slope and counter-slope,

fjeld and fjord, &c. Take, for example, one of the specific subjects for the higher standards. In physical geography the following is one of the items:—"The nature of a river or stream, whence it is supplied, and what becomes of it."

In this model we have each of these topics variously illustrated:—

I.—*The nature of a river.* It is seen to be water draining off the land, flowing through valleys, finding its way to lower levels, till it reaches the ocean.

II.—*Whence it is supplied.* In the model we see the source far up among the mountains; there are the snowy peaks which feed the glacier stream, there are the hill lochs and the chains of lakes, there are the river basins with the tiny rivulets trickling down the hill sides till they form tributaries joining the river at the confluence.

III. *What becomes of it.* In the model we give several examples of this: in one case the river terminates its course in the low-lying swampy country, and flows into the ocean through the numerous channels of a delta; in another the river flows unencumbered by bar or other obstruction with a straight course into the sea, presenting facilities for safe navigation; while in another example the river has cast up a sand bank in the middle of its estuary.

There is another light in which we may regard the usefulness of Alto-Relievo in Geographical Education—that is to say, as a true interpreter of the map. In maps it is possible to represent mountain heights by graded lines and shaded colours only, and at the best much depends upon the eye of the spectator bringing with it the power of seeing what the map-draughtsman desires to represent. For instance, in a truly fine map of the British Isles, which I now show, mountains are coloured brown, and the increase of *height* is indicated by a *deeper* shade, while the sea is coloured blue, and increase of *depth* is indicated also by a *deeper* shade. Depth of colour is thus employed in the map to indicate *increased height*, and also *increased depth*. It is thus evident that the spectator has to do a good deal for the map in the way of understanding it. This is just what the scholars cannot at first give. But the Alto-Relievo Model, by its raised surface and its various levels, enables the merest tyro to comprehend the meaning of the map signs by comparing them with the real country as displayed according to nature in the model.

Apropos of the subject—the place of geographical relief in education,—it may be stated that the model finds a very fit place at home, suspended to the constant view of the pupil in the lesson-learning room. In short, it is a most interesting aid in home-study and in the preparation of lessons at home—not the least important school being the home school.

Hitherto I have spoken of the place of Alto-Relievo in Geographical Education. But there is another very important department of education—History. Here also the Alto-Relievo Model assists most powerfully. It is certainly a pity that history consists so greatly of the marchings and counter-marchings of armies, and of battles fought and won; yet such as it is teachers and scholars must study it. Now, if, for instance, the historical study in a school be the Peninsular War, the scholar does not find in the political wall-map any sufficient indication of the physical conditions which so largely influenced the direction of the campaign. But one glance at the model of Spain enables the veriest dunce to understand why the armies marched from S.-W. to N.-E. along the great valleys, instead of steeple-chasing over the *sierras* from N. to S., or from S.-E. to N.-W. He sees that the surface of the country determined the drift of battle quite as surely as it still determines the flow of the Tagus and the Douro.

Similarly, if the school, in its classical side, is studying the invasion of Italy by Hannibal, or in its modern side, that other incursion by Napoleon, the model of Italy lays before the pupil in enchanting verisimilitude those celebrated mountain passes through which the armies poured down upon the great fighting ground of Italy—the level plains of Lombardy.

In closing these remarks upon the place of Alto-Relievo in Education, it may be interesting to some if I refer briefly to the special adaptations introduced by my firm to meet the case of the Blind. For them the map has no lesson, but we can at once appreciate the suitability of the Alto-Relievo Model. Yet there are certain details in which the model requires some addition to adapt it to the blind. They can readily feel the rising slopes and the bold mountain chains, but they cannot feel the towns, nor the lakes and lochs and low-lying coasts. For them the model needs some addition. The models which I now show contain these additions, viz.:—

I. The land surface is roughened, so that the smoothness of the inland seas and broad lochs is at once felt.

II. The rivers are marked in wire, and the wire is somewhat raised above the roughened surface, so that the sensitive fingers may trace the river from source to sea, without coming too much in contact with the rough land.

III. The cities are marked by round-headed tacks, the capitals being a little larger.

IV. Low-lying islands are marked by flat-headed tacks.

Models adapted in this manner to the wants of the blind have been supplied to the Institutions in Edinburgh, Glasgow, Dundee, &c., and as far afield as San Francisco; and in this department also highly appreciative testimonials have been received from the teachers.

In conclusion, permit me to thank you for the invitation to bring these matters before you this evening, and for the considerate attention you have given to the subject—a consideration which you must allow me to attribute more to your well-known enthusiasm in the subject than to anything in the manner in which I have presented it.

During the reading of the paper the following models of continents, countries, &c., were submitted for inspection:—

Europe, Asia, Africa, North America, South America, and Oceania—22½ inches by 18½ inches each.

The European countries (seven models in the set)—average size, 10 inches by 10 inches each.

Europe—36 inches by 30 inches.

Italy, with the Alps—36 inches by 30 inches.

Scotland—33 inches by 26 inches.

The Geographical Forms and Physical Features, with Nomenclature—45 inches by 37 inches.

Specially adapted for the Blind, the following:—

Europe, Asia, Africa, North America, South America, and Oceania—22½ inches by 18½ inches each.

GRAHAM LECTURE.

XI.—*On certain Modern Developments of Graham's Ideas concerning the Constitution of Matter.* By T. E. THORPE, Ph.D., B.Sc. (Vict.), V.P.C.S., F.R.S., Professor of Chemistry, Royal School of Mines and Normal School of Science, London. *Third Triennial "Graham" Lecture delivered before the Society in Anderson's College, 16th March, 1887.*

THERE is a certain fitness in our selecting this place to do honour to-night to the memory of Thomas Graham. For it was in the chemical laboratory of this Institution that Graham carried out, upwards of half-a-century ago, the experimental investigations which culminated in his memorable discovery of the law connecting the rate of movement of a gas with its density. This law combined with that of Boyle, which connects the volume of a gas with the pressure to which it is subjected, and with the law of Charles, which expresses the relations of the volumes of gases to heat, has done more to give precision to our knowledge of the constitution of matter than all the speculations of twenty centuries of schoolmen.

Graham was made Professor of Chemistry in the Andersonian Institution in 1830, and it was from here that he gave to the world his classical paper "On the Law of the Diffusion of Gases," read before the Royal Society of Edinburgh, December 19th, 1831. I am fully conscious that my only claim to be regarded as worthy to pronounce this eulogium of Graham arises from the circumstance that I also have had the good fortune to hold the lectureship of Chemistry in this place; and with forerunners like Birkbeck, Gregory, and Graham, I may well be proud of an honourable and distinguished ancestry. This association with the Andersonian Institution naturally quickened my interest in Graham and his works, and my frequent opportunities of conversation with the late Dr. James Young, of Kelly, who for so many years was its President, and who was, as we all know, also one of Graham's "discoveries," and for a long time, both here and in London, one of his most trusted assistants, enabled me to learn much of Graham's personal character and mode of work. On the occasion of the gift of Brodie's fine statue of Graham to the city by Dr. Young, it

fell to my lot to prepare the short biographical notice of my distinguished predecessor, which, with other papers relating to the matter, is, I understand, deposited in the archives of your Corporation. And I may be pardoned, perhaps, for recalling with what mingled feelings of pride and trepidation I set myself to the execution of that task.

In the preface to the admirable reprint of Graham's papers, which we also owe to the filial piety of Dr. James Young, the late Dr. Angus Smith has indicated in precise and even luminous language Graham's position in that chain of thinkers which includes Leucippus, Lucretius, Newton, and Dalton. Indeed, of all Angus Smith's papers with which I am acquainted, there is none, to my thinking, more charming than this little introductory essay of a dozen octavo pages, in which, with unwonted perspicacity, he has defined Graham's place in the history of speculative philosophy. In this paper Angus Smith has crystallised out, as it were, the thoughts of a lifetime of literary research and meditation. Probably no man—certainly no contemporary of Graham's—was better fitted by knowledge and by sympathy to form a sound critical estimate of such a position than the biographer of John Dalton. Angus Smith's mind was simply steeped in the old Hellenic philosophy. To him even Kapila was more than a name, and the atomic systems of India were matters of more than conjecture or of passing interest. There was much in Smith's intellectual nature to make such inquiries congenial to him. With all his leaning towards objective science, he had a Highlander's love of the mystical, and a Lowlander's passion for metaphysics. And yet nothing is more admirable than the manner in which in this essay these qualities and this wealth of learning are subordinated and held in check; and nothing is more striking than the way in which in a few graphic strokes, done with a master hand, lightly yet firmly, with a consciousness of power and a sense of restraint, Graham's place in the evolution of the atomic philosophy is set forth.

It is here claimed for Graham that he was a true descendant of the early Greeks, and that to him belonged as of right the mantle of Leucippus. Atoms and Eternal Motion were as much fixed articles of his creed as they were of that of Heraclitus. But with no one of the older Greeks was Graham's thought more in harmony than with that of Leucippus. He with his wider knowledge of the so-called "elemental" forms of matter, and of the

persistency with which the specific properties which we associate with our "Elements" are retained, could yet share with the old Greek his conceptions of the essential oneness of matter. It was with Graham, as Smith says of Leucippus, that "the action of the atom as one substance, taking various forms by combinations unlimited, was enough to account for all the phenomena of the world. By separation and union, with constant motion, all things could be done."

In one respect Graham's position as an atomist is unique. No man before him had dedicated his life to the study of atoms and atomic motion. These fundamental ideas are intertwined to make up, so to say, the silver thread which runs through the work of forty years. They were the dominant conceptions of his life. Even in his earliest paper, published when he was just twenty-one, in which he treats of the absorption of gases by liquids, we are able to detect in the phraseology employed that his mind had been already permeated by the notion of atomic movement. That he should be familiar, even at this time, with the conception of atoms in the Daltonian sense is hardly surprising, when we remember that he had already come under the influence of Thomas Thomson, whose place in the history of science is probably that of the first great exponent of Dalton's theory of chemical combination. But the idea of motion was never with Dalton an integral or essential part of his theory, nor in so far as it was necessary as serving to explain the phenomena of chemical union, was it held by Thomson. And this is the more remarkable when we remember that Dalton had discovered for himself the fact of the molecular mobility of a gas, and that his first glimpses of the truth of his great law were obtained by the study of the chemical combination of gases. Graham was doubtless cognisant in a general way of the speculations of the early Greeks, but there is no evidence in any of his writings, nor has anything been preserved in the reminiscences of his friends and contemporaries to indicate that he was knowingly influenced by them. This continuity of idea is, indeed, the most striking characteristic of Graham's labours: all his work seemed to centralise round this fundamental conception of atomic motion. "In all his work," says Smith, "we find him steadily thinking on the ultimate composition of bodies. He searches after it in following the molecules of gases when diffusing; these he watches as they flow into a vacuum or into other gases, and observes carefully as they

pass through tubes, noting the effect of weight and of composition upon them in transpiration. He follows them as they enter into liquids and pass out, and as they are absorbed or dissolved by colloid bodies, such as caoutchouc; he attentively inquires if they are absorbed by metals in a similar manner, and finds the remotest analogies, which, by their boldness, compel one to stop reading and to think if they be really possible. He follows gases at last into metallic combination, and the lightest of them all he makes into a compound with one of the heavier metals, chasing it finally through various lurking-places until he brings it into an alloy and the form of a medal, and puts upon it the stamp of the Mint. Indeed, he is scarcely satisfied even with this, and he finds in bodies from stellar spaces—in meteoric iron—this same metallic hydrogenium, which he draws out from its long prison in the form of a gas. . . . . If we examine his work on Salts and on Solutions we have a similar train of thought. One might have slighted the importance which he attached to the water of salts, and the temperature at which it was reduced, but in his hands it was a revelation of some of the most mysterious internal phenomena of these bodies.

"A chemist must take great pleasure in following Graham when he seeks the laws of the diffusion of liquids, and traces their connections, especially when they lead to such results as he expressed by dialysis, a process founded on a new classification of substances, and promising still the most valuable truths. We see in the inquiry how Graham thought on the internal constitution of bodies, by examining the motion of the parts, and from the most unpromising and hopeless masses under the chemist's hands—amorphous precipitates of alumina or of albumen—brought out analogies which connected them with the most interesting phenomena of organic life. Never has a less brilliant-looking series of experiments been made by a chemist, whilst few have been so brilliant in their results, or promise more to the inquirer who follows into the wide region opened."

In a short paper entitled "Speculative Ideas respecting the Constitution of Matter," originally published in the *Proceedings* of the Royal Society for 1863, Graham has left us his Confession of Faith upon the subject to which he had devoted the whole of a thoughtful life. He conceives that the various kinds of matter, now recognised as different elementary substances, may possess one and the same ultimate or atomic molecule existing in different

conditions of movement. Graham traces the harmony of this hypothesis of the essential unity of matter with the equal action of gravity upon all bodies. He recognises that the numerous and varying properties of the solid and liquid, no less than the few grand and simple features of the gas, may all be dependent upon atomic and molecular mobility. Let us imagine, he says, one kind of substance only to exist—ponderable matter; and further that matter is divisible into ultimate atoms, uniform in size and weight. We shall have one substance and a common atom. With the atom at rest the uniformity of matter would be perfect. But the atom possesses always more or less motion, due, it must be assumed, to a primordial impulse. This motion gives rise to volume. The more rapid the movement the greater the space occcupied by the atom, somewhat as the orbit of a planet widens with the degree of projectile velocity. Matter is thus made to differ only in being lighter or denser matter. The specific motion of an atom being inalienable, light matter is no longer convertible into heavy matter. In short, matter of different density forms different substances—different inconvertible elements, as they have been considered.

It should be said that Graham uses the terms atom and molecule in a wider sense than that which the limitations of modern chemistry have imposed upon them, and that he is referring to a lower order of molecules or atoms than those which more immediately relate to gaseous volume. The combining atoms of which he conceives the existence are not the molecules of which the movement is sensibly affected by heat, with gaseous expansion as the result.

According to Graham the gaseous molecule must itself be viewed as composed of a group or system of the inferior atoms, following as a unit laws similar to those which regulate its constituent atoms. He is, in fact, applying to the lower order of atoms ideas suggested by the gaseous molecule, just as views derived from the solar system are extended to the subordinate system of a planet and its satellites. We cannot as yet fix any limit to this process of molecular division. To Graham the gaseous molecule is a reproduction of the inferior atom on a higher scale. The diffusive molecules, the molecules or systems which are affected by heat, are to be supposed uniform in weight, but to vary in velocity of movement, in correspondence with their constituent atoms. Hence, the molecular volumes of different elementary substances

have the same relation to each other as the subordinate atomic volumes of the same substances.

On this basis Graham builds up a conception of chemical combination. He points out, in the first place, that these more and less mobile, or light and heavy, forms of matter, have a singular relation connected with equality of volume. Equal volumes of two of them can coalesce together, unite their movement, and form a new atomic group, retaining the whole, the half, or some simple proportion of the original movement and consequent volume. Chemical combination thus becomes directly an affair of volume and is only indirectly connected with weight. Combining weights are different because the densities, atomic and molecular, are different. The volume of combination is uniform, but the fluids measured vary in density. This fixed combining measure—Graham's *metron* of simple substances—weighs 1 for hydrogen, 16 for oxygen, and so on with the other "Elements."

Graham, however, points out that the hypothesis admits of another expression. Just as in the theory of light we have had the alternative hypotheses of emission and undulation, so in molecular mobility the motion may be assumed to reside either in separate atoms and molecules, or in a fluid medium caused to undulate. A special rate of vibration or pulsation originally imparted to a portion of the fluid medium enlivens that portion of matter with an individual existence, and constitutes it a distinct element or substance.

The idea of the essential unity of matter finds its analogy, to Graham's thinking, in the continuity of the so-called physical states of matter. He clearly perceived that there is no real incompatibility in the different states of gas, liquid, and solid. These physical conditions are, indeed, often found together in the same substance. The liquid and the solid conditions supervene, as Graham puts it, upon the gaseous condition rather than supersede it. They do not appear as the extinction or suppression of the gaseous condition, but as something *superadded* to that condition. Graham conceives that the three conditions (or constitutions) probably always co-exist in every liquid or solid substance, but one predominates over the others, just as the colloidal condition or constitution which intervenes between the liquid and crystalline states extends into both, and probably affects all kinds of solid and liquid matter in a greater or less degree. Hence, to Graham's thinking, the predominance of a certain

physical state in a substance appears to be a distinction analogous to those distinctions in natural history which are produced by unequal development. Liquefaction or solidification does not involve the suppression of the atomic or molecular movement, but only the restriction of its range.

Such, then, are Graham's ideas, formulated in 1863, respecting the probable constitution of matter. I have purposely stated them in great detail, and, for the most part, in Graham's own words. The paper is very short but it has evidently been put together with great care, and it is impossible not to be struck with the evidence it affords of Graham's insight, his grasp of principles, and power of co-ordination. Consider, for example, what he says respecting the continuity of the so-called physical states of matter, and bear in mind upon what an extremely small experimental basis it rested at that time. The observations of Cagniard de la Tour were almost forgotten, or at all events their significance was not understood. The classical work of Andrews was not yet published. And yet this work, combined with that of a dozen experimentalists in France, Russia, and Germany, has only served to confirm and expand Graham's fundamental conception. The whole paper shows Graham in a very different light from that which the student of to-day might be apt to regard him. The greater number of his memoirs are mainly the records of measurements, but Graham was not a great measurer in the sense in which we apply that term to such men as Regnault, Magnus, or Bunsen. Very little of his work was done by his own hands, and it must be confessed that the earlier experimental portion was occasionally entrusted to apparently inexperienced assistants. Graham had, however, the *förscherblick* which characterises the true investigator, and he possessed a really marvellous faculty of sifting out the small grain of fact which often lay hidden beneath a mass of imperfect observation. And yet he was in no hurry to theorise. He patiently added fact to fact, repeating and verifying his observations long after he had got an inkling of the truth towards which they were tending. He laboured like Faraday, *ohne Hast, ohne Rast*, and his work is a monument of patient concentrated thought, and of a singleness of purpose which never swerved.

"Experimentarian philosophers" of Graham's type (to use a phrase which Hobbes of Malmesbury once flung at the progenitors of the Royal Society) have very similar intellectual tendencies. One is insensibly led to compare Graham with the greatest of

our English atomists, John Dalton. If you will turn to Dr. Henry's "Life of Dalton," and read the charming analysis of Dalton's mental characteristics, made by one who knew him well, and who had studied him carefully, you will find that practically all that is there stated is equally applicable to Graham. Both men were pre-eminently endowed with the faculty of contemplating abstract relations of space and number, and each began his researches with the expectation that all empirical phenomena were to be brought under the control of mathematical laws. Thus Dalton strove to prove that the changes produced in the gaseous and liquid states of matter vary as the square, cube, or some other simple function of the temperature. Graham, in like manner, sought to show that the movement of his diffusive molecules, whether in liquids or in gases, was related to some equally simple function of their mass. Henry says of Dalton that "his inmost mental nature, and all its outward manifestations were, in the language of the German metaphysicians, emphatically subjective. Thus in special or objective chemistry he has left absolutely no sign of his presence; no great monograph on an individual body and its compound; no memorable analysis of a substance deemed simple, into yet simpler elements; no new element—no Neptune—added to the domain of chemistry." Every word of these sentences could be applied with equal truth to Graham. The tendencies of both men were essentially introspective. Each was capable of the most patient and concentrated thought, and of steady prolonged attention, wholly abstracted from external objects and events. I have heard the late Dr. Young narrate the most extraordinary instances of Graham's power of mental abstraction. Dalton said of himself that "If I have succeeded better than many who surround me, it has been chiefly, nay, I may say, almost solely from unwearied assiduity. It is not so much from any superior genius that one man possesses over another, but more from attention to study and perseverance in the objects before them, that some men rise to greater eminence than others."

It seems like a contradiction in terms, when we reflect for a moment upon the characteristic features and tendency of his work, to say that Graham, like Dalton, was utterly devoid of the quality we call imagination. Henry says of Dalton that imagination had absolutely no part in his discoveries, except, perhaps, as enabling him to gaze in mental vision upon the ultimate atoms of

matter, and as shaping forth those pictorial representations of unseen things by which his earliest as well as his latest philosophical speculations were illustrated. Graham would not even allow his fancy that amount of play. Even in the speculative essay from which I have quoted so largely, it seems as if every word had been weighed, and every sentence put together with slow laborious thought. This passionless aspect of his work seems to have greatly impressed Angus Smith, himself a man of lively sympathy and of quick susceptibility. "His works," says Smith, "are full of care, but not of joy."

A quarter of a century has elapsed since Graham formulated his conceptions concerning the constitution of matter. I wish now to indicate, as briefly as may be, how these conceptions have developed during these five-and-twenty years.

The idea of the essential unity of matter has a singular fascination for the human mind. It may be that it has its germ in the persistency with which every mind, even that of a child, seeks to get at first principles. The most superficial reader of the history of intellectual evolution cannot fail to perceive how greatly it has modified and directed the development of scientific thought. The whole course of chemistry, for example, has been controlled by this fundamental conception. The half-educated student of to-day may smile at the notion of the transmutation of the metals which held such sway over the minds of the early alchemists, but the men who followed this *ignis fatuus* with weary faltering steps, and who frequently sunk under the burden of disappointed hope and the sense that to them it was not given to know the light, felt that this idea rested on a rational basis. They, like ourselves, could give a reason for the faith that was in them; and yet no article of scientific doctrine has, in these later times, suffered greater vicissitudes. Men's ideas concerning the essential unity of things must have received a rude shock when it was found that such a thing as water was not only complex, but was made of bodies strangely contrasted in properties; that the air was still less simple in composition; and that, as it appeared, almost every form of earth could, by torture, be made to give up some dissimilar thing. The brilliant discoveries of Davy which made the early years of this century an epoch in the history of science seemed to open out a vista to which there was no conceivable ending. The order of things was not towards simplification, it tended rather towards complexity; and yet Davy himself seemed unable

or unwilling to push his way along the path of which the world regarded him as the pioneer. It may be that he was unable to shake himself free from the domination of the school-men, or that he unconsciously felt the truth of the principle to which his own discoveries seemed opposed. It is difficult otherwise to account for the tardiness with which he accepted the hypothesis of Dalton; even to the last the Daltonian atom had nothing distinctive to Davy beyond its combining weight. Davy never wholly committed himself to a belief in the indivisibility of the atom: that indivisibility was the very essence of Dalton's creed. In arguing with a friend concerning the principle of multiple proportion, Dalton would clinch the discussion by some such statement as "thou knows IT MUST BE SO, for no man can *split an atom.*" Even Thomas Thomson, whom I have already characterised as the first great exponent of Dalton's generalisation, was torn by conflicting beliefs until he found peace in the hypothesis of Prout and Meinecke that the atomic weights of all the so-called elements are multiples of a common unit, and which he sought to establish by some of the very worst quantitative determinations to be found in chemical literature. It is curious to note the bondage in which the old metaphysical quibble concerning the divisibility or indivisibility of the atom held the immediate followers of Dalton. Graham, however, never felt such trammels; to him the atom meant something which *is not* divided, not something which *cannot* be divided. With Graham, as with Lucretius, the original atom may be far down. Every philosophic thinker to-day has, I should imagine, come to be of this opinion. Not many years ago it was the fashion to maintain that Stas's great work had for ever demolished the doctrine of the primordial *ylé*, and that Roger Bacon's aphorism that "barley is a horse by possibility, and wheat is a possible man, and man is possible wheat," was henceforth an idle saying. Stas's work is a monument of experimental skill, and it has furnished us with a set of numerical ratios which are among the best determined of any physical constants. It may be that it demolished Prout's hypothesis in its original form, but it has not touched the wider question; whether indeed the wider question is capable of being reached by direct experiments of the nature of those of Stas is very doubtful, unless the weight of the common atom is some very considerable fraction, say one-half or one-fourth of that of the hydrogen atom. Dumas has, as you know, modified Prout's hypothesis in this sense by assuming as the common divisor half

the atomic weight of hydrogen, but there is no *á priori* reason why we should stop at this particular subdivision. The exact relation of Stas's work to Prout's law has, I think, been fairly stated by Professor Mallet at the conclusion of his admirable paper on the Atomic weight of Aluminium, in the *Philosophical Transactions* for 1880 (vol. 171, 1033). Stas's main result, says Mallet, "is no doubt properly accepted if stated thus, that the differences between the individual determinations of each of sundry atomic weights which have been most carefully examined are distinctly less than their difference, or the difference of their mean from the integer which Prout's law would require. But the inference which Stas himself seems disposed to draw and which is very commonly taken as the proper conclusion from his results, namely, that Prout's law is disproved, or is not supported by the facts, appears much more open to dispute. It must be remembered that the most careful work which has been done by Stas and others, only proves by the close agreement of the results that *fortuitous* errors have been reduced within narrow limits. It does not prove that all sources of constant error have been avoided, and indeed this never can be absolutely proved, as we never can be sure that our knowledge of the substances we are dealing with is complete; of course, one distinct exception to the assumed law would disprove it, if that exception were itself fully proved, but this is not the case. As suggested by Marignac and Dumas, anyone who will impartially look at the facts can hardly escape the feeling that there must be some reason for the frequent recurrence of atomic weights differing by so little from accordance with the numbers required by the supposed law." Professor Mallet, in tabulating the atomic weights which may be fairly considered as determined with the greatest attainable precision, or a very near approach thereto, and without dispute as to the methods employed, points out that out of the 18 numbers so given, 10 approximate to integers within a range of variation less than one-tenth of a unit. He then proceeds to calculate the degree of probability that this is purely accidental, as those hold who carry to the extreme the conclusions of Berzelius and Stas, and he finds that the probability in question is only equal to 1: 1097·8, and he concludes that not only is Prout's law not as yet absolutely overturned, but that a heavy and apparently increasing weight of probability in its favour, or in favour of some modification of it, exists and demands consideration.

It would be impossible for me to attempt to traverse the whole ground of this question which has been opened up during the past fifteen or twenty years. Even if I could claim the time and your indulgence, there is hardly the necessity for such a demand on your patience. Mr. Crookes, only so recently as September last, gave an admirably complete exposition of the present state of the case in his address to the Chemical Section of the British Association at the Birmingham Meeting, and for me to go over the ground again with you would be simply to plough with Mr. Crookes' heifer. Some years ago, Mr. Norman Lockyer, as you doubtless know, approached the subject from another point of view, and in his recent work, "The Chemistry of the Sun," you will find a summary of the evidence which the spectroscope has afforded us concerning the dissociation of "elementary" matter at such transcendental temperatures as we have in stars like the sun.

Now when we pass in review all this evidence; when we reflect upon the mode of distribution of the elements and especially their tendency to associate in correlated groups; when we bear in mind the absolute analogy which exists in the general behaviour and mode of action of the radicles which are confessedly compound with those which are assumed to be simple; when we have regard to the phenomena of allotropy, isomerism, and homology, the mind insensibly appeals to the principle of continuity and refuses to believe that the seventy and odd "elemental" forms, to which our processes of analysis have reduced all the kinds of matter we see around us, differ in essence from bodies which are known to be compound.

The connection between the properties of the "elements" and the relative weights of their atoms, as developed by Newlands, Mendelejeff, Lothar Meyer, Carnelley, and others, has served to strengthen this conviction. The discovery that the physical and chemical properties of the elements are as periodic functions of their atomic weights is unquestionably the most important generalization we have had in chemical philosophy during the last five-and-twenty years. Its bearings upon the question of the origin of the "elements" have been worked out in the Presidential Address I have already referred to. Mr. Crookes, like Mr. Lockyer before him, in seeking to apply to this question of the genesis of the "elements" the same principles of evolution which Laplace has already applied to the creation of the heavenly bodies, and which Lamarck, Darwin, and Wallace have applied to that of the

organic world, is again appealing to the law of continuity. The mind which holds that nature is one harmonious whole is fain to believe that the probability that the elements have originated by chance, and are eternally self-existent, is just as remote as that the animals and plants of to-day are primordially created things. I think, in what I am now saying, I may fairly claim to be reflecting the opinion on this matter of every philosophic thinker of to-day. Nay more: you must allow that the germ which has been kept alive for so many centuries, and which has come down to us through the brains of a succession of thinkers like Leucippus, Aristotle, Lucretius, Bacon, Newton, Dalton, and Graham, has become quickened and endowed by the light which modern science has shed upon it from all sides with a vitality which will persist and strengthen.

Having thus traced the development of the idea held by Graham of the essential oneness of matter, let us spend the few remaining moments in considering, in the most general way, how the science of the last twenty-five years has worked out and extended his conceptions concerning the properties of the atom and its mode of motion.

The treatment which "the few grand and simple features of the gas," to quote Graham's phrase, have received at the hands of Clausius, Clerk-Maxwell, Helmholtz, Sir William Thomson, and a score of workers in this country and on the Continent who have been actuated by their influence, has served to dispel much of the metaphysical fog which has enshrouded the notion of the atom, and to-day we are able to reason about atoms, as physical entities, having extension and figure, and of their number and dimensions and peculiarities of movement, with the confidence which is based on well ascertained facts. We have, of course, not yet attained to a complete molecular theory of gases. But we know the relative masses of the molecules of various gases, and we have calculated in miles per second their average velocity. The phenomena of diffusion indicate that the molecules of one and the same gas are all equal in mass. For, as was pointed out by Clerk-Maxwell, if they were not, Graham's method of using a porous septum would enable us to separate the molecules of smaller mass from those of greater, as they would stream through porous substances with greater velocity. We should thus be able to separate a gas, say hydrogen, into two portions, having different densities and other physical properties, different combining weights, and probably

different chemical properties of other kinds. As no chemist has yet obtained specimens of hydrogen differing in this way from other specimens, we conclude that all the molecules of hydrogen are of sensibly the same mass, and not merely that their mean mass is a statistical constant of great stability. (See Art. "Atom," *Ency. Brit.*, 9th ed.) This line of argument has, it seems to me, an important bearing upon a question which has been raised by Marignac, Schutzenberger, and others, and which has again been raised by Mr. Crookes in the address I have already referred to. Mr. Crookes thinks that it may well be questioned whether there is an absolute uniformity in the mass of every ultimate atom of the same chemical element, and that it is probable that our atomic weights merely represent a mean value, around which the actual atomic weights of the atoms vary within certain narrow limits, or in other words, that the mean mass is "a statistical constant of great stability." The facts of diffusion would seem to lend no support to such a supposition.

Graham was still living when Loschmidt published what Exner calls his epoch-making paper "On the Size of the Air Molecule." Although the numerical estimate which Loschmidt deduced from the mean free path of the molecules and their volume has now only an historical interest, it has exercised a profound influence on the development of molecular physics in demonstrating that in dealing with molecules we are dealing with masses of finite dimensions, and further that these dimensions are by no means immeasurably small. The very manner in which Loschmidt stated his conclusions was well calculated to rivet attention. He showed that these magnitudes, small as they are, are yet comparable with those which can be reached by mechanical skill. The German optician Nobert has ruled lines on a glass plate so close together that it requires the most powerful microscope to observe the intervals between them; he has drawn, for example, as many as 4,000 lines in the breadth of a millimeter, that is about 112,000 lines to the inch. Now if we assume with Maxwell that a cube whose side is the 4,000th of a millimeter is the smallest volume observable at present, it would follow that such a cube would contain from 60 to 100 millions of molecules of oxygen or nitrogen; and if we further assume that the molecules of organised bodies contain on an average 50 "elementary" atoms, it further follows that the smallest organised particle visible under the microscope contains about two million molecules of organic matter. And as at least

half of every living organism is made up of water, we arrive at the conclusion that the smallest living being visible under the microscope does not contain more than about a million organic molecules. I could have wished, had time permitted, to have dwelt a little upon the intensely interesting questions which such a conclusion at once raises. In the article "Atom" in the present edition of the *Encyclopædia Britannica*, from which I have quoted, you will find Clerk-Maxwell points out its relation to physiological theories, and especially to the doctrine of Pangenesis. "Molecular science," says Maxwell, "forbids the physiologist from imagining that structural details of infinitely small dimensions can furnish an explanation of the infinite variety which exists in the properties and functions of the most minute organisms."

In the year following Graham's death Sir William Thomson still further developed the modes of molecular measurement, and from a variety of considerations, based upon the kinetic theory of gases, upon the thickness of the films of soap bubbles, and from the electrical contact between copper and zinc, he arrived at estimates which, although sensibly different from that of Loschmidt, are still commensurable with it. In a subsequent lecture to the Royal Institution, given about four years ago, he extended the lines of his argument and arrived at the conclusion that in any ordinary liquid, transparent solid, or seemingly opaque solid, the mean distance between the centres of contiguous molecules is less than the one five-millionth and greater than the one thousand-millionth of a centimeter; and in order to give us some conception of the degree of coarse-grainedness implied by this conclusion, he asks us to imagine a globe of water or glass, as large as a football, to be magnified up to the size of the Earth, each constituent molecule being magnified in the same proportion. The magnified structure would be more coarse-grained than a heap of small shot, but probably less coarse-grained than a heap of footballs. (*Nature*, July 19, 1883.)

Here I think we may leave the subject, at all events for to-night. I am painfully conscious that I have left unsaid much that ought to have been said, and possibly said some things that might well have been left unsaid. But my main purpose will have been served if I have succeeded in indicating to you Graham's position as an atomist, and in showing you how his ideas respecting the constitution of matter have germinated, and, like the seed which fell upon good ground, have borne fruit an hundredfold.

XII.—*An Examination of the Report of the Royal Commission on Depression of Trade:* Address inaugurating the Economic Science Section. By Mr. CHARLES GAIRDNER, President of the Section.

[Read before the Society, 2nd March, 1887.]

WE meet to-night for the purpose of opening within the Philosophical Society a new Section to be devoted to Economic Science. That this is a development suited to the time is shown by many indications. The conditions of commerçe, and the relations between capital and labour, between producer and consumer, between debtor and creditor, are continually changing, and out of these changes arise questions which require to be examined and discussed if we would avoid falling into error. Such discussions are largely carried on now by means of pamphlets and newspaper correspondence, with little educative result considering the enthusiasm displayed. We propose to improve upon this by creating an arena where papers carefully prepared may be read and debated. The movement has already received encouraging support, not only from the members of the Society, but from more than fifty associates who have given in their adhesion, and from whom we anticipate much of the energy which will give life to the Section. I only wish you had found a president better fitted for the post, and more abundantly endowed with the leisure it is desirable he should have. As it is, I willingly undertake that what I can do in making our work a success shall be done with cordiality and devotion, and I thank you very sincerely for the honour you have done me in appointing me to be your first president.

To-night I should like to consider with you, in the first place, the kind of subjects which are likely to prove interesting and suitable for our purpose. Economic science is a comprehensive term, and while I would not begin by limiting its scope, I would, nevertheless, suggest that our papers and discussions should, as a rule, have a practical aim. In an active and intelligent community like this we are seldom without burning questions of one

kind or another affecting our material interests. These interests will give a sense of reality to our discussions, and I think it will generally be found that those who combine a knowledge of detail with a firm grasp of sound general principles will come off best in debate. Those of us who are getting up in years, and who can remember the great Parliamentary debates of thirty and forty years ago, which preceded the present era of commercial freedom, are apt to suppose that the questions settled then have without doubt been settled for ever. But as I grow older I see more clearly the danger of this assumption, and the need for constant and reiterated exposition even of economic principles which may be regarded as elementary.

Even if our system of commerce were ideally perfect, it would be subjected to trials. Our cycles of fat and lean years have their origin, to all appearance, in natural causes. The lean years prove trying to the weak and improvident, and create doubts and misgivings as to whether "something" should not be done for their relief. The government—that is to say, Jupiter—is in such cases sure to be called upon. A little protection against the competitor across the water would, it is seen, make all the difference between a loss and a profit. Why should the struggling trader not have this protection, and so save himself and workmen from wreck and ruin? At heart, I fear, every man in that day of trial becomes a protectionist; and if it be so clearly good for him, why should it not be good for all? So runs the argument from the point of view of the individual trader. From that of the nation it is another affair, which, as we shall presently see, has also a good deal to say for itself. Considerations such as these make it necessary that instruction in economic science shall form part of the education of every citizen, so that not merely at school and at college, but daily throughout our lives, we shall be able to apply sound principles to the solution of the ever-changing social problems we have presented to us.

I have stated that the time is favourable for opening this Economic Science Section. If evidence be required of this we find it, I think, in the fact that we have been, and still are, passing through a particularly perplexing time in the economical affairs of the world. To whatever cause it may be attributable, we have had a remarkable progress downwards in prices in all the gold currency countries, prolonged over many years, and accompanied by great disturbance in the relations between all persons

possessed of property or engaged in industrial pursuits. So serious has this become that we have had a Royal Commission appointed to investigate its "extent, nature, and probable causes, and whether it can be alleviated by legislative or other measures." The need for examination and discussion of what has thus come to be generally called the "Depression of Trade" is rendered none the less, but rather the more, urgent, because now that the Report of the Commission has been presented—containing, as it does, a large amount of valuable information—we find that the Reporters have failed to agree on any important practical conclusion. We find that the inquiry was committed to 23 men, presumably competent for the duty, and that while 18 of the number have agreed on a joint Report, no fewer than 11 of these have found it necessary to qualify their concurrence by separate Reports. An independent Report has been made by four of the remaining members, one of whom, again, appends a second explanatory Report; and the twenty-third member has found it necessary to have a Report entirely to himself. The main Report is evidently a compromise between men of different opinions, and so its conclusions are almost of necessity disappointingly feeble. This want of agreement, however, which takes from the Report much of its practical usefulness, makes it all the more serviceable for our purpose. The subjects it treats of are of the gravest national importance, and have been examined by men of opposite modes of thinking. The evidence taken is in great measure that of the best-informed men—including such names as Sir James Caird in Agriculture, Sir Lowthian Bell in Iron, Martineau and Neil in Sugar, Giffen in General Statistics, as well as many other representatives of Capital and Labour whose opinions are of the highest value. The blue-books containing the Reports and evidence have, by my request, been furnished to the Library, and I commend them to your diligent examination.

One of the first things for which you will naturally look in examining the Report is a definition of the phrase—"Depression of Trade." In the chief Report you will find it explained to be "a diminution and, in some cases, an absence of profit, with a corresponding diminution of employment for the labouring classes." From the point of view of the trader this definition is, perhaps, sufficiently accurate; the thing which he complains of, and which depresses him, is undoubtedly want of profit. But it does not follow from this that his experience illustrates the whole case.

The Commissioners were instructed to report whether the depression could be "alleviated by legislative or other measures," and before legislation can be called into operation it is necessary to discover whether the want of profit applies only to a particular class or to the whole nation, whether the loss of one section of the people may not have been compensated by the gains of another. Until facts such as these have been cleared up it is premature to discuss the remedy.

How then stands the fact? Can it truly be said that there has been a diminution or complete absence of national profit in recent years? Before we can answer the question it is necessary to consider wherein the profit or gain of the nation through trade and commerce consists. The answer cannot be presented in the compendious form of pounds, shillings, and pence. That is the natural and appropriate mode for a trader to ascertain and express the result of his trading, but it has no applicability to the aggregate trading of a nation. The gains of a nation by trade do not correspond with the aggregate gains of its traders—a fact of great importance which, I fear, has not been always remembered by the Royal Commissioners.

In considering the national gains you must not look to the money which the trader uses as a part of his machinery, but to the things themselves which form the national wealth. The whole money within the country represents but a fraction of one per cent. of its aggregate wealth. The true wealth consists in those interchangeable commodities which serve to satisfy the wants of the people. Have these things increased or decreased in volume? On the answer to this question depends the gain or loss of the nation within any defined period.

It may be that some portion of my audience have not had occasion to consider this view of the trading of a nation with the attention it deserves, and as it has a direct bearing on the subject referred to by the Royal Commission I may be pardoned for following up the subject a little further. In the admirable volume of the late Professor Cairnes on "Some leading principles of Political Economy," he devotes part of a paper to the subject of the gain on foreign trade. Having exposed the fallacy of the theories of the "balance of trade" and the "excess of imports over exports" as exhibiting the profits or losses of a trading nation, he shows "that the end and purpose of all trade is to cheapen production, and so to minister more effectually to the ultimate end—the need of the consumer.

True, the trader's motive is to make a profit, but not the less is his *raison d'être* as a trader to minister to the wants of others. He must have his profit or he will cease to trade; but his profit, though an incident of the good resulting from his office, is not the measure of it; that consists in the benefit he confers on the community whose servant he is, and this benefit is great in proportion to his success in serving the consumer, in other words, in cheapening the commodities, in diminishing the obstacles that exist to the satisfaction of human wants. Nothing can betray a more profound misconception of the true nature of trade and the purpose for which it exists, than to represent the advantages derivable from it as measured by the profits of the agents who carry it on. It would be just as reasonable to represent the advantages of learning as measured by the salaries of the teachers."

The teaching of Professor Cairnes is in complete harmony with that of Adam Smith, who tells us that "consumption is the sole end and purpose of all production; and the interest of the producer ought to be attended to only so far as it may be necessary for promoting that of the consumer." These are principles to be kept constantly before us when considering a nation's trade from the imperial point of view, and yet we find one of the most energetic of the Royal Commissioners, in direct opposition to Cairnes and Adam Smith, recording as his opinion that "it is the first duty which a State owes to its citizens to protect their industries from invasion, and that a government which confesses its impotence or professes its reluctance to fulfill that duty, abdicates one of its primary functions." Here is a fundamental question treated in quite antagonistic fashion by different members of the Royal Commission. When the State interferes in the affairs of trade and commerce shall it be in the interest of the consumer or the producer? Adam Smith and the economists say in the interest of the consumer alone. Nay, say the reactionaries, you must protect the industries of the country by legislating in support of the producer.

But, how are we to deal with the question—Has there, or has there not, been in recent years a diminution in the profits of the nation as a whole? It is to be done by inquiring whether the aggregate of national wealth has been increasing or diminishing; whether the aggregate or volume of trade has been increasing or diminishing. In the consideration of these questions we must, as I have already said, exclude altogether the idea of money,

which from the national point of view is merely an intermediary. The money value of commodities is of the utmost importance in relation to the transactions of individuals, and I shall have occasion before I conclude to refer to and emphasise the fact; but in looking, as I am now doing, to the interests of the nation as a whole it may be altogether excluded. Whether, then, with Professor Fawcett, we define national wealth to comprise "every commodity which has an exchange value," or seek for some more perfect definition, it is the increase or diminution of this wealth in the aggregate, which marks the increase or diminution of the gains of the nation. And in the same way as regards the trade of the nation, it is the increase or diminution of its *volume*, which we must look to, and not to the increase or diminution of its *value* expressed in money.

The answers to these questions, as now explained, will be found in the Report of the Royal Commissioners, not, indeed, in categorical form, nor yet with all the importance assigned to them which they deserve, but still brought out with sufficient clearness and precision. They report "a general agreement among those they have consulted that neither the volume of trade nor the amount of capital invested therein, has materially fallen off." This is extracted from the main Report (clause 27) which I have ventured to think is characterised by the tame neutrality of a compromise. Individual Commissioners pronounce on the point with greater emphasis, one declaring that the figures presented to them "illustrate clearly and prove conclusively *the continued growth of the trade of this country in volume*, and its activity."

I have been thus particular in raising the question whether the depression arises from decay in the wealth and trade of the country as a whole, or from some other causes; because, until so important a question has been settled, any attempt to "alleviate the position by legislative or other measures" might not improbably, through ignorance, do more harm than good. I now assume it to be the fact that, whether the rate of progress in increasing wealth be as rapid as formerly or not, progress to some extent continues to be made, and that there is no such falling-off in the rate of progress as to account for the depression in trade which has been so generally complained of in recent years. Had the conclusion pointed in the other direction, had it been shown that the volume of trade and the wealth of the nation had been falling off, a different problem would have been set before us, and one probably much

more difficult to solve. As it is we may, I believe, confidently assume that the wealth of the country, as a whole, is being maintained and increased; and that being so, we must look within the limits of the nation itself for the causes of the disturbance and for the remedies, if any, to be applied.

It will be impossible for me within the time to which I must restrict myself to present, except in the most cursory manner, the different causes which, in the opinion of the witnesses examined by the Commissioners, have contributed to bring about the state of things complained of. I am anxious, however, to enumerate them, because I believe they will be found to suggest several subjects of interest suitable for discussion at meetings of the Section. The first in order, as reported by the Commissioners, is Over-production. This, as a reason assigned for depression in trade, is perhaps the most ordinary and frequent. If you happen to meet a trader whose trade is depressed, and ask him what is wrong, there are ten chances to one he will tell you there is over-production. Most probably he will say that he can't get cost price for his goods, and from this fact he draws the inference that there is over-production. Yet it may be that there is no over-production whatever in the true sense of the term, that is to say, production in excess of the consumptive power of the world. What he really means is over-production at a particular price, which is quite a different matter. This is, and is likely to continue to be, an ordinary incident of every trade, and the remedy may come, either through diminished production or through diminished cost of production. In the case of commodities which are consumed within the year, and are again reproduced with next season's crop, there is usually a fairly rapid adjustment of supply to demand. In less perishable commodities, again—those, for example, which have been called "instrumental"—such as iron, machinery, ships, and the like, which do not depend on the harvest of each year, over-production at a particular price, when it arises may be expected to take longer to return to the equilibrium which allows the trader or producer his steady profit. The essential cause of the loss in such cases, regarded from a general point of view, is not over-production but disproportionate production, and the loss sustained by the producer or seller is, though not wholly, to a large extent compensated by the gain to other sections of the people. This disproportionate production is a familiar incident in business, and is responsible for many fluctuations in prices, but

it is quite inadequate to explain a general or universal fall in prices; and there is no reason to doubt that, notwithstanding the complications and serious sacrifices which it entails on individuals, it will best adjust itself in the future as in the past, by being left in the hands of those chiefly concerned with it, uncontrolled by state interference. As regards over-production in the abstract, it is, perhaps, enough to say with Professor Fawcett, "no doubt it is possible, as a hypothesis, to suppose that a greater quantity of all commodities may be produced than people really want, but such an over-production has never taken place in the past, and is never likely to occur in the future."

The second alleged cause of depression deduced by the Commissioners from the evidence taken by them is—"The continuous fall of prices caused by an Appreciation of the Standard of Value." This important branch of inquiry, however, has, at the request of the Commission, been remitted to a separate Royal Commission specially appointed for the purpose. It has, therefore, been passed by without investigation or serious remark, and I defer for the present my observations upon it.

The third cause relates to the effect of Foreign Tariffs and Bounties, and to the restrictive commercial policy of foreign countries in limiting our markets. The influence, both direct and consequential, exercised by hostile tariffs, and the best mode of meeting trade obstructions of this description, have acquired new interest in recent times by the extent to which the Bounty system is carried, especially in the sugar trade. This presents an attractive field of inquiry, and creates the best opportunities for the convinced Fair Trader. He will find allies on the Royal Commission who have done their best to provide him with arguments, and I will only say to-night that I hope the subject will be freely debated until conclusions clear and sound in regard to it have been evolved by discussion and adopted by the Section.

The fourth cause is Foreign Competition. This raises the question of how far we are falling behind our neighbours in competing in the markets of the world. Special mention is made of Germany as taking precedence of us in certain quarters, and it is plainly stated by the Commissioners that they are impressed with the fact that there is some "falling off among the trading classes of this country from the more energetic practice of former periods" (76). This is a suggestion of considerable value which ought to be turned to account.

Under the fifth cause we have "Increase in Local Taxation and the burdens on Industry generally." Some of the questions which may be classed under this head are well to the front for early treatment by the legislature, and will probably receive recognition when Parliament finds time to deal with Local Government. The incidence of Taxation as between Capital and Labour, as between the small capitalist and the larger one, and generally the least inconvenient modes of raising the necessary funds for Imperial and Local purposes, are full of that kind of interest which begins at home, and present many points requiring discussion.

There remain, sixthly, the cheaper Rates of Carriage enjoyed by our neighbours, suggesting for consideration the readjustment of railway rates, and the advantages or disadvantages of railways being taken over by the State. Seventhly, Legislation affecting the employment of Labour, on which I shall have a few words presently to say; and eighthly, superior Technical Education of workmen in foreign countries. This last has of late begun to attract public attention, and it is to be earnestly hoped that it will not be allowed to rest until in every mercantile and manufacturing community opportunities are afforded to the youth of the country of technical training in the industrial arts. In this respect we are undoubtedly behind Germany and the United States, and I hope we may look forward to the preparation of papers on the subject which shall bring out by comparison our national defects, and point the way to remedies which shall be efficient not in this community only but throughout the whole country.

Having thus enumerated the causes of importance which, in the opinion of the witnesses examined, have contributed to the existing depression of trade, the Commissioners proceed to discuss them individually, with the result that they declare they have "few definite recommendations to make." Improved education, increased vigilance, search for new markets, some changes with regard to transport by railways and canals comprise the whole. This seems a small result to come from so much labour, but it is valuable as showing how little under a free system of commerce the State can do for us. The evidence goes, on the whole, to show that the depression of which we complain appears to be in the main an affair of adjustment between the various subdivisions of the great workshop in which we live.

Yet, it is not quite accurate to say that our industrial system is

altogether free. We have Factory Acts—legislative enactments in restraint of labour. We have Trades' Unions, under which the workmen are by no means free to dispose of their labour as they individually choose. Have these restrictive influences no bearing on the depression, and, if so, may we not look to the Legislature for relief? I have already mentioned that the Royal Commissioners had their attention called to this question by some of the witnesses, and the result of their inquiries and the opinion they have formed are perhaps the most gratifying portions of their Report. They say that neither the restrictions imposed by the Legislature on the employment of labour, nor those by the action of the working-classes themselves, have, in their opinion, materially affected the prosperity of the country. And further, "with regard to the comparative efficiency of labour carried on under the conditions which prevail in this country and foreign countries, respectively, while there would appear to be great difference of opinion, those who have had personal experience of both, appear to incline to the view that the English workman, notwithstanding his shorter hours and higher wages, is to be preferred." They, therefore, do not recommend any legislative measure tending to an increase in the hours of labour. This is a most important conclusion, and not more important than it is satisfactory. Wages will no doubt rise and fall with changing circumstances, but that the shortening of the labour hours to the extent which now prevails, should have led to at least a corresponding increase of efficiency, is pure gain to the nation as well as to the workman. The Report goes on to say—"There is no feature in the situation which we have been called upon to examine, so satisfactory as the immense improvement which has taken place in the condition of the working-classes during the last twenty years. At the present moment there is, as we have already pointed out, a good deal of distress owing to the want of regular work, but there can be no question that the workman in this country is, when fully employed, in almost every respect in a better position than his competitors in foreign countries, and we think that no diminution in our productive capacity has resulted from this improvement in his position."

So far, I have dealt with the Report of the Commissioners, and, although it is no part of my purpose to-night to present in any prominent way my own opinions upon it, yet it is impossible for me not to point out that the object of the inquiry has been to a

large extent defeated, from the exclusion by the Commissioners of the principal factor in the problem they had under consideration. Before we can safely prescribe for a patient there must be a diagnosis, and to exclude from the diagnosis the most conspicuous fact in the case is not a usual or very promising mode of proceeding. The question to be investigated was the "extent, nature, and probable causes" of a derangement in the industrial machinery of the country. One of the most refined and sensitive parts of the machinery is money, from which comes the element of price, an element which influences every other part—forming, indeed, the connecting band between all the parts, giving life and motion to each, and acting as the adjuster and moderator between them when friction arises. A great change has come over this element of price in recent years, and much disturbance has undoubtedly been caused thereby in the machinery. According to one set of thinkers this has arisen from a change intrinsic to money itself, whereby prices have been, in all probability, permanently forced down. According to others it is not so; to them the change seems due to causes of ordinary occurrence. Some hold it is beyond the reach of legislative action. Others say, not so, the remedy is simple and easy of application.

What is beyond dispute is that a great shrinkage has taken place in the value in gold coin of almost every kind of property. This, perhaps, would be of small account if there were no such relations as debtor and creditor; no such things as contracts, legal or conventional, over extended periods, to pay certain rates of annuity, wages, salaries, rents. But for these everything would quickly settle down to the new range of prices. The fact, however, is far otherwise. The relations of debtor and creditor, the existence of protracted pecuniary contracts in one form or another, are in this country the rule, rather than the exception. The debt of the debtor continues to stand for its full nominal amount in gold, while the debtor's property, valued in gold, has shrunk 20, 30, 40 per cent., as the case may be. The "new way of paying old debts" is thus tantamount to an aggravation of the debt, and in some cases amounts to a crushing calamity. This has been most conspicuously seen in connection with land and other real estate held under mortgage, and not in Ireland only, but also in England and in Scotland. In the case of wages, no doubt, the effect is different, because in course of time they ought to, and indeed must, be adjusted to the new value of

money; but here, too, there is much friction and consequent loss. The old wages, from some apparently spontaneous cause, have become endowed with a higher purchasing power. In effect, the terms have become more favourable to the workman, more onerous to the employer; but the change having sprung from no act of either is naturally recognised but slowly by the party benefited. Thus have arisen differences, misunderstandings, strikes. The position of the capitalist-employer, exposed on the one hand to depreciation of his property, and on the other to hostile relations with his workmen, has thus been most harassing. Is it to be wondered that under such circumstances we have had depression? Rather should we wonder and inquire how the distress has not been greater. The reason is not far to seek; it is in the fact that the course of events has favoured the consumers, the wage-receiving classes—in a word, the *many*,—and that at the expense of the propertied classes, who are the *few*. The Report of the Commission fully establishes this, and sets forth that "while the general production of wealth in the country has largely increased, its distribution has been undergoing great changes; that the result of these changes has been to give a larger share than formerly to the consumer and the labourer, and so to promote a more equal distribution."

The fall in prices, then, is to all appearance the chief factor in the depression of trade, and it was surprising to learn, as we did in June last, that the Royal Commission appointed twelve months before to investigate and report on the subject had resolved to exclude altogether from their consideration the question of gold and silver. Yet this is what has been done. A new Commission has been appointed to consider this particular subject, and we must wait for its Report before we shall have an authoritative opinion on the question whether "legislative or other means" can afford relief. I have no intention of speculating on the probable verdict, but it may be useful to look at what is being contended for on the one side and the other.

According to one party, of whom Mr. Giffen is the most important member, the State should leave the matter alone. If this be done, the prospect is that, unless we have a large addition to our gold supplies, the gradual tendency in the future, from generation to generation, must be toward lower prices. This somewhat gloomy prospect, as it will be generally considered, is qualified by the assurance that the progress downwards is not

likely to be at anything like the rate we have experienced in the last ten years. The fall during that period he distinguishes into what he calls "catastrophic," because of its originating in the adoption of a gold currency by certain countries formerly using silver—a disturbing influence of an altogether exceptional nature, not likely to recur; and "natural," arising from the supply of gold from the mines being inadequate to maintaining the old relative value of gold to other commodities. The future fall may thus be very gradual, and of comparatively little account.

According to the party representing the other extreme, we are, by Act of Parliament, to restore silver to its old importance as currency, and to its relative value to gold. That, in so far as this country is concerned, is, I apprehend, a proposal to change our standard of value, the effect of which would be a great and rapid rise in prices. Whether or not such a scheme is practicable or desirable is a question on which to-night I express no opinion. It has been seriously proposed and supported by men who ought to be listened to, and who, no doubt, will be listened to by the new Commissioners. The issues involved are, indeed, far-reaching, and I commend them to the consideration of the Economic Science Section, assured that both sides will receive careful exposition, and be subjected to all the criticism their importance deserves.

The Report of the Royal Commission is chiefly valuable for the evidence which has been collected. In itself it is inconclusive and disappointing, and this feeling is mingled with regret that it should be the last Parliamentary work of a statesman who, more than any other of his time, had secured, as the reward of a life-time spent in the service of his country, the affectionate regard of both the great parties in the State.

XIII.—*The Aboriginal Australian, as he was.* By ARTHUR KAY.

[Read before the Society, 2nd February, 1887.]

To have been once wild is no disgrace. In Australia we can see what our forefathers may have sprung from. A true child of nature, the Aboriginal is *the* novelty for travellers in our greatest colony to study. If we only could write his history, and tell whence he and his language came, had we but a full record of his traditions and myths, what a grand second, mayhap first, chapter they might make for "A History of Man." Yesterday, he and his fellows ran wild over a great continent; to-day, unless beyond the confines of civilization, they wander tame and rare over their scanty hunting lands.

The sketch to be laid before you this evening does not lay claim to any accuracy of system in treating of the Aborigines, nor does it enter into details as to the names and districts of the tribes whose habits are described. They have general habits, cast of feature, and language, in common, but there the sameness ceases. You will understand, then, that when some strange custom is mentioned, in all likelihood it belongs to a few tribes and is not general throughout the continent.

Travellers differ in their tales of the colour and form of the Australians. One gives them coal-black skins, bottle-noses, spider-legs, and ferocious countenances; another makes them models of symmetry, with their colour a touch of brown, scarce dark enough to hide a blush; while the greater number look upon them merely as "blacks," having a conformation like that of the pure African negro. The fact is, Australia is a large continent, and few travellers have seen and known all the varieties of the Aborigines, who differ about as much in stature, bulk, and colour, as Britons, Germans, French, and Italians. When well fed they are tall, stout, and well developed; but those dwelling in desert tracts, where large game

is scarce, are thin, spider-limbed, and generally speaking, "poor specimens"—as unlike as a Yorkshire farmer and the proverbial poor curate. The well-fed ones, when in their prime, are symmetrical, and show good muscular development. They all grow coarse bushy beards.

Some New South Wales tribes consider a man's best point to be the possession of shins which are very concave forwards. A man whose shins are convex forwards is ridiculed by his fellow blacks, especially by the women, who say "legs all same boomerang." The women do not match the men in looks, and cannot compare with young African girls. In old age they are hideous hags, with faces like parchment-covered skulls. This is owing very much to the hard life they lead. Wives are the camels of Aboriginal Australia, but get less kindly treatment than those useful beasts of burden. An anecdote tells us that some natives who, for the first time, saw oxen drawing a wagon, wondered what these animals might be; some held that they were spirits, but the majority that they were the white men's wives, because they carried the burdens.

This strange race has its myths. These form the primitive Old Testament of the Aborigine, and may seem to you frivolous and hardly worthy of notice—a mere garbled account of early missionary teaching; but, in truth, there is little reason to doubt them. Most probably, with one exception, they are ancient as the Aborigine himself.

Pund-jel, or Bun-jil, created all things, save women. Pund-jel has a wife, Boi-boi, whose face he never looked upon; yet was a son, Bin-beal, born to him. He had also a brother, Pal-ly-yan. Pund-jel always carried a great knife, with which he went over the earth, and cut it up into creeks and rivers, mountains and valleys. He had also an instrument, named Berrang; with this he could open anything, and no one knew how he had entered. Pund-jel fashioned two male blacks. With his great knife he cut three big sheets of bark, on one of which he put some clay, and kneaded it; when the clay was soft, he took part to one of the other pieces of bark, and began to shape it into a man, making the feet first, and the head last. He made another man on the third piece of bark. Being well pleased with his work, he gazed at the men for some time, and then danced round about them. He next took some stringy bark, and having made hair of it, placed it on their heads; to one man he gave curly hair, to the other straight.

Pund-jel again gazed on his work, right pleased, and again danced round the men; the one with straight hair he called Ber-rook-boorn, the one with curly hair Koo-kin-berrook. He then lay upon each of them, and blew his breath into their mouths and nostrils, and breathing very hard they moved; yet a third time he danced round about them, then he made them speak and stand up, and they appeared as full-grown young men, not like children. But they were wifeless waifs. Pal-ly-yan, said to be a brother, sometimes a son of Pund-jel, is god of the waters; rivers, creeks, lagoons, and likewise the great sea, obey him. All creatures that dwell in the depths or the shallows are under him; his chief joy is to splash about the shallows, or dive in the deepest depths. One day he was gambolling in a deep water-hole, he thumped and threshed the water with his hands, even as the women beat the skins when men dance the corrobboree; the water became as mud, and Pal-ly-yan could not see. Dividing the thick waters with a bough, he beheld what seemed to be hands, such as Pund-jel had given to the men he had created; and then there appeared two heads, such as Pund-jel had given to the men, then bodies, and finally two creatures, like Mon-mon-deek, young women. He brought them to show to Pund-jel, who gave to each man a woman and a spear; and Pal-ly-yan gave to each woman a digging stick, and told them and the men to live together. Pund-jel and Pal-ly-yan tarried with the blacks for three days, teaching the men hunting, and the women how to dig roots; on the third day there came a great storm, and the whirlwind and the great storm bore Pund-jel and Pal-ly-yan upwards, far away, and the blacks saw the gods no more.

The Dieyerie tribe tradition is as follows:—The Moora-moora (good spirit) created a number of small black lizards, and being pleased with them he promised them power over all other creeping things. He then divided their feet into toes and fingers, and placing his forefinger on the centre of the face, created a nose; and so in like manner afterwards, eyes, mouth, and ears. The Moora-moora then placed one of them in a standing position, this it could not retain, so the Deity cut off the tail and the lizard walked erect. They were then made male and female so as to perpetuate the race.

The Murray Aborigines have an account of how death came into the world, but it seems so probable that the story has filtered through some missionary, that it is best passed over.

Another legend tells how Pund-jel became wroth with the peoples of the earth for their wickedness, and scattered them hither and thither. A Western Australian legend says there were first two beings, male and female; they had a son who got a deadly wound which his parents could not heal, whereupon the first man vowed that all who came after him should die in like manner as his son died. The story goes on to say that, although dead and in his grave, the son did not stay there, but rose and went to the west, to the great unknown land of spirits beyond the sea; his parents followed, and not being able to persuade him to come back, they abode there with him.

The Lake Tyers tribes relate how once there was no water anywhere on the face of the earth, all was in the body of a huge frog, and mankind could get none. A council was held, and it was agreed that if the frog could be made to laugh the waters would run out of his mouth, and there would be plenty in all parts. Several animals danced and capered before him, but he remained as solemn and stupid as any ordinary frog, even though their gestures were enough to make mirth anywhere. All the animals tried, and failed. At length the eel began to dance on his tail, and the frog's jaws opened, he smiled, he laughed out, and the waters came forth from his mouth, and there was a flood. Many perished in the waters. The Pelican, who before the flood was a black fellow, resolved to save the black people; he made a great canoe, and sailed among the islands which rose here and there out of the wide waters, and taking the people into his canoe, kept them alive.

A most curious superstition, and one pointing to the antiquity of the Australian Aborigines, is that relating to the kidney fat. Of old, idolaters offered the fat from the loins and the kidney fat of human victims as a pleasing gift to the gods. The Jews offered the same part of animals typically. (Leviticus iii. 3-4.) Among the ancient Greeks—"the fat of victims which his friends bestow." (Virgil, Æn., b. vi., 121-2.) When alone, and far from the camping ground of his tribe, the Aborigine believes himself in danger of losing his kidney fat by the spirit of some wild black.

The Australian is often unwilling to give his real name, no doubt owing to the fear that through it some sorcerer might harm him. The Tasmanians dreaded any mention of their names. From early ages many nations have held the name to be a vital part of the very being of its bearer, and sorcerers have used it, so that by incantations they might transfer the personality of their victim

place. Tasmania does not seem to have been peopled prior to the land connection between it and Australia. During the Pleistocene period, when it formed part of the continent, huge mammals existed in the forests and plains. These probably became extinct before the southern districts were peopled. At any rate, no vestige of native art has been found associated with their well-nigh unaltered bones. Still, as already indicated, if a people so low in condition as the Tasmanians had co-existed with the great mammals, any trace of their wanderings would have been hard to find.

The physical characteristics of the Tasmanians are against any theory that connects them with the present continental tribes. If the island was peopled from Australia, the continental race at that time must have been Tasmanian in language and conformation. This would drive us to the conclusion that the race now found on the continent is intrusive. Dr. Latham proposes that the stream of population for Tasmania flowed round Australia, not across, and gives as reason that Tasmania and New Caledonia have stronger affinities in language than Tasmania and Australia.

No man has yet proved the origin of the Australian race. The physical geography of the area might suggest that the continent was peopled from Timor; and the occurrence of Australian words in the dialects of Ombay and Timbora strengthens this suggestion. More probably a race came across Torres Straits. If so, it is fair to assume that there would be two great streams from the Northern Peninsula. One might make for the south-east shore of the Gulf of Carpentaria, and there divide, a section wandering westwards and southwards towards Western Australia, and thence to King George's Sound; the other taking along the course of the rivers that flow towards Cooper's Creek and the Darling. The second great stream would go down the east coast, westwards, and may in time have reached Gippsland. The dialect of the lower Murray tribes resembles that of the natives north of the Darling. The Western Australian natives have weapons like those used in the north-west. They seem to have only one kind of shield, such as is found in Queensland, but quite unlike that used in the south, and they use spears like those of the north coast people. The people of Queensland and the Perth tribes ornament the wooden part of their adzes with the same peculiar longitudinal grooves. If the local names used by the blacks were carefully preserved and studied, they might become very valuable sources of information.

There are many curious characteristics which the Australians have in common with other races. A child's first name depends very often on some incident at its birth, such as a kangaroo or other animal passing suddenly, or the birth happening at some landmark, or under some particular species of tree. In Genesis xxx. we have "And Leah said, a troop cometh, and she called his name Gad." A like custom is followed by the Bedouins. Kaffir children often get their names in the same way. Panda, King of the Zulus, was really U-mpande, a name derived from Impande, a kind of root. The Australian's objection to tell strangers his name has been referred to: the Kaffir shows a like reluctance.

In South-Western Australia certain shining stones or crystals, called Teyl, are held in great veneration. Only priests and sorcerers dare handle them, and an unqualified man cannot be persuaded to touch them. This word in sound and meaning strangely resembles the Baetyli mentioned in the following extract from Burder's Oriental Customs:—"'And Jacob rose up early in the morning, and took the stone that he had put for his pillow, and set it up for a pillar, and poured oil upon the top of it, and he called the name of that place Bethel.' (Gen. xxviii. 18.) From this conduct of Jacob, and this Hebrew appellation, the learned Bochart, with great ingenuity and reason, insists that the name and veneration of the sacred stones called Baetyli, so celebrated in Pagan antiquity, were derived. These Baetyli were stones of a round form; they were supposed to be animated by means of magical incantations with a portion of the Deity; they were consulted on occasions of great and pressing emergency as a kind of divine oracle, and were suspended either round the neck, or some other part of the body." In Victoria Mr. A. W. Howitt obtained a magic stone from an old man; it is egg-shaped, and weighs 27 ounces. Being thickly covered with oxide of iron, its composition cannot be ascertained without breaking it. The natives called it Bulk, and their sorcerers valued it very highly.*

* In Threlkeld's vocabulary the following extract occurs:—"Mur-ra-mai: The name of a round ball, about the size of a cricket ball, which the Aborigines carry on a small net suspended from their girdles of opossum yarn. The women may not see the interior of the ball. It is used as a talisman against sickness, and is sent from tribe to tribe for hundreds of miles on the sea coast and in the interior. One is now here from Moreton Bay, the interior of which a black showed me privately in my study,

Mitchell says:—"In their girdles the men, and especially their Koradjees or priests, frequently carry crystals of quartz, or other shining stones, which they hold in high estimation, and are very unwilling to show to any one, invariably taking care when they do unfold them that no woman shall see them."

In Australia the mother-in-law dare not look upon her present or future son-in-law, and the son-in-law hides himself if he chances to see his mother-in-law coming his way. A Kaffir covers his eyes and shuns his wife's mother, and the like strange fear of meeting or seeing a mother-in-law has been noticed in South America, in Araucania, and amongst savages in other parts of the globe—and even in Britain in the nineteenth century. This practice is also prevalent in many parts of Polynesia.

The custom of ordeal by combat prevailed among the Australians. In England even, judicial combat only became strictly illegal when the law was struck out of the statute book in 1819.

We now come to the initiation ceremonies which young men have to undergo when they come of age. These vary very much with the districts in which they take place. The Victorian youth had merely to endure a few grotesque and painless follies; but in other parts the ordeal was so severe that it frequently destroyed those who were not of the most robust health; and the lad who showed any sign of fear was either murdered or disgraced for life and put to work with the women. Women might not behold these savage scenes, and their intrusion was visited with the penalty of death.

In those parts of Africa where similar rites prevail, the fetish man blows a whistle made of hollowed mangrove wood, probably as a signal for the uninitiated and the women to keep away, just

---

betraying considerable anxiety lest anyone should see its contents. After unrolling many yards of woollen cord, made from opossum fur, the contents proved to be a quartz-like substance of the size of a pigeon's egg. He allowed me to break it and retain a part. It is transparent, like white sugar-candy. They swallow the small crystallized particles which crumble off as a preventive of sickness. It scratches glass, and does not effervesce with acids. From another specimen the stone appears to be agate, of a milky hue, semi-pellucid, and strikes fire. The vein from which it appears to be broken off is one inch and a quarter thick. A third specimen contains a portion of carnelian partially crystallized, a fragment of chalcedony, and a fragment of a crystal of white quartz."

as the Witarna* is used in Australia. The natives put every obstacle in the way of Europeans wishful to see these rites. An Australian poet says:—

> "Not ours the wisdom or the light
> To shadow forth that solemn rite;
> Nor what the word, nor what the way,
> That moulds a man from boyish clay."

When the hair on a youth's face deserves to be called beard, he is made Narumbe, Kaingani, or young man, in order that he may be considered an equal by the men of his own tribe; numerous representatives of other tribes must attend the ceremony. The main object of this custom is to prevent any tribe admitting among the men those who are not really of age, and thus too rapidly increasing their supply of marriageable males. This is a very important consideration in a country where each tribe has to obtain women from an adjacent one. For no man is allowed to choose a wife, except from outside his own tribe, all members of which are looked upon as being of one family.

As a rule two youths are made Kaingani together, in order that they may afterwards help each other when they are Narumbe. Suddenly, at night, the men seize and take them some distance from the wurley, the women all the while attempting, or pretending, to save the lads. The victims are then stripped; their moustaches and beards are plucked out, and a spear point serves to tear out their matted hair. From top to toe they are smeared with oil and red ochre. During three days and three nights a strict watch is kept over the Kaingani; they dare not eat or sleep, and may only drink a little water by sucking it through a reed; for months no drinking vessel is allowed. The third day ended they are allowed to sleep, with two sticks stuck crosswise in the ground for a pillow. During six months they must walk naked, and the ceremony generally takes place in winter. The state of Narumbe lasts until their beards have twice been plucked out, and each time have grown about two inches. Woman's food, and twenty kinds of game are forbidden them, and everything they have or obtain is Narumbe, or sacred from women's touch. Any one breaking the rules of Kaingani, or Narumbe, the old men punish with death.

* The Witarna is a piece of wood which is tied to a long string, and it is then swung round the head in such a manner as to cause a low rumbling sound, which increases or decreases according to the will and effort of the performer.

[illegible]

she may be dragged by the hair or knocked on the head with a club, or some other gentle means may be used to induce obedience. If the bride is still obstinate, perhaps the father or brother will spear her in the leg or foot.

Sometimes a girl is betrothed in infancy. When the man dies before she is marriageable, his heir claims her. Very fleshy beauties are great favourites with the gentlemen, and many a warrior will risk his life to obtain so great a prize.

A lone bachelor, without female relatives, is sure to be an object of suspicion, for he needs to steal a wife, or go without. If he chooses the former course, he must undergo the ordeal of having spears thrown at him by those who consider themselves aggrieved. A meeting in public takes place; a spear and shield are given to the offender, and with these he must parry and avoid the spears thrown at him. Generally, after being severely wounded, he is allowed to keep his stolen wife. Sometimes, if a man shows unusual address in warding off and avoiding the spears, he may be allowed to keep his wife, although he is not wounded.

There is no wedding ceremony among the Aborigines, such as that which among less uncivilised races makes public the contract. This leads some to infer that there is promiscuous intercourse; such, after marriage, as a rule is not the case. When a man gets a good wife, he gets a useful and valuable asset. The woman does most of the work, and carries the household property. The man supplies animal, his wife finds vegetable food.

Infanticide has been a custom among the natives, but it seems to have arisen from necessity rather than from cruelty. Often because the mother could not carry two children, or on account of some weakness or deformity in the infant, when twins were born, one, sometimes both, perished. The instinct of maternal love for a favourite child is strongly engrained in the Australian Aboriginal woman. She will gladly die to save it. If a loved one dies, she keeps it still; placing the tiny body in a bag, she bears it with all that her master and husband bids her. Day after day she labours with her burden through the lonely forest, amid the wilderness of gum trees, weeping now and again as the senseless clay sadly strikes her sides, and seems to upbraid her for the roughness of the way. At night, in camp, it is put in a safe spot, and not the most frivolous among the young folk dare mock the mother for her sacred duty. Like regard is paid to any deceased

notable. The hands are cut off, and the nearest relatives bear these mementoes with them and hold them sacred.

The natives had various burial customs. A few tribes, with certain rites, consumed the corpse on a funeral pile; others interred the body beneath the bed of a running stream, like the Obongos, a West African tribe. This brings to mind the passage in Gibbon's "Decline and Fall," where the burial of Alaric the Goth is thus described:—"The ferocious character of the barbarians was displayed in the funeral of a hero whose valour and fortitude they celebrated with mournful applause. By the labour of a captive multitude they forcibly diverted the course of the Busentinus—a small river that washes the walls of Consentia. The royal sepulchre—adorned with the splendid spoils and trophies of Rome—was constructed in the vacant bed; the waters were then restored to their natural channel, and the secret spot where the remains of Alaric had been deposited was for ever concealed by the inhuman massacre of the prisoners who had been employed to execute the work." The commonest method of the Australian Aborigine was doubtless to inter the body. Major Mitchell has thus described the tomb of Milmeridien:—"This burial ground was a fairy-like spot, in the midst of a 'scrub' (grove) of drooping acacias. It was an extensive space, laid out in little walks, which were narrow and smooth, as if intended only for sprites. All these ran in gracefully curved lines, and inclosed the heaving heaps of reddish earth which contrasted finely with the acacias and dank casuarinas around. Others, gilt with moss, shot far into the recesses of the bush, where slight traces of still more ancient graves proved the antiquity of these simple but touching records of humanity. With all our art we could do no more for the dead than these poor savages had done."

Death begets death. The blacks cannot believe that any man dies from natural causes, and therefore must have revenge on the fancied enemy who has compassed the decease of their friend or relative. It is generally the duty of the sorcerers or Koradjees during, or immediately after, the burial, to tell where the man is to be found who has contrived the death of an Aboriginal. One method is to cover the grave with wet clay; this the mourners sit and watch, until the heat of the sun cracks it. The path which the avengers are to take is indicated by the direction of the first fissure which shows itself in the drying clay. Their duty is to

bring back the kidney fat of the first man of another tribe whom they meet.

It is the custom of the Narrinyeri (who inhabit the Lakes and Lower Murray) for the nearest relative of the dead man to sleep with his head on the corpse. It is thought that the dreams dreamt on this pleasant pillow direct the dreamer to the person who has caused his friend's death.

The writer has been asked to say if cannibalism was practised by the Aborigines. To some extent no doubt it was. Natives killed and ate little children, and the flesh of warriors slain in battle was sometimes eaten. Feasts on human flesh did not prevail as among the Fijians, but the natives seem to have eaten certain parts of the bodies of the slain in obedience to superstitious customs. Human life was rarely taken merely for purposes of nutrition, unless a tribe was starving. The Maori, who dwelt in a region better supplied with food, was a notorious cannibal. The natives of Fraser Island (Great Sandy Island), Queensland, feasted on human flesh; fat young men and women suited their palate. Long ago, tribes in parts of New South Wales (Bathurst, Goulburn, the Lachlan or Macquarie), in obedience to a religious ceremony, used to eat the first-born of every lubra. There is a well-authenticated case of a black fellow who had been thrown, when an infant, on the fire. He was rescued and brought up by some stockkeepers who chanced to pass. The scars caused by the burns were visible on him when a man, and his story was well known in the locality.

An Aboriginal's daily life was troublous, and he lived in fear of his foes. At times he dared not light a fire, lest it should guide his enemies to him. Often he himself had some wrong or fancied wrong to redress. Mayhap while the men were away at the chase the camp would be attacked. On their return the hunters would find the young women taken to be wives for their enemies and the old ones murdered.

Their domestic life was simplicity itself. A fire was enough, no cooking utensils were needed; there might be a wooden drinking bowl, and a large grass bag for holding food. The man also used a small grass bag for his private effects, these would consist of some round stones (Boolk or Bulk), to make his enemies sick; a packet wrapped in bark and painted with red ochre—the fat of some enemy he has slain; a few other odds and ends indicate an eye to business; round his middle is wrapped in many folds a cord spun from opossum fur, in which are stuck his hatchet, boomerang, and

notable. The hands are cut off, and the nearest relatives bear these mementoes with them and hold them sacred.

The natives had various burial customs. A few tribes, with certain rites, consumed the corpse on a funeral pile; others interred the body beneath the bed of a running stream, like the Obongos, a West African tribe. This brings to mind the passage in Gibbon's "Decline and Fall," where the burial of Alaric the Goth is thus described:—"The ferocious character of the barbarians was displayed in the funeral of a hero whose valour and fortitude they celebrated with mournful applause. By the labour of a captive multitude they forcibly diverted the course of the Busentinus—a small river that washes the walls of Consentia. The royal sepulchre—adorned with the splendid spoils and trophies of Rome—was constructed in the vacant bed; the waters were then restored to their natural channel, and the secret spot where the remains of Alaric had been deposited was for ever concealed by the inhuman massacre of the prisoners who had been employed to execute the work." The commonest method of the Australian Aborigine was doubtless to inter the body. Major Mitchell has thus described the tomb of Milmeridien:—"This burial ground was a fairy-like spot, in the midst of a 'scrub' (grove) of drooping acacias. It was an extensive space, laid out in little walks, which were narrow and smooth, as if intended only for sprites. All these ran in gracefully curved lines, and inclosed the heaving heaps of reddish earth which contrasted finely with the acacias and dank casuarinas around. Others, gilt with moss, shot far into the recesses of the bush, where slight traces of still more ancient graves proved the antiquity of these simple but touching records of humanity. With all our art we could do no more for the dead than these poor savages had done."

Death begets death. The blacks cannot believe that any man dies from natural causes, and therefore must have revenge on the fancied enemy who has compassed the decease of their friend or relative. It is generally the duty of the sorcerers or Koradjees during, or immediately after, the burial, to tell where the man is to be found who has contrived the death of an Aboriginal. One method is to cover the grave with wet clay; this the mourners sit and watch, until the heat of the sun cracks it. The path which the avengers are to take is indicated by the direction of the first fissure which shows itself in the drying clay. Their duty is to

bring back the kidney fat of the first man of another tribe whom they meet.

It is the custom of the Narrinyeri (who inhabit the Lakes and Lower Murray) for the nearest relative of the dead man to sleep with his head on the corpse. It is thought that the dreams dreamt on this pleasant pillow direct the dreamer to the person who has caused his friend's death.

The writer has been asked to say if cannibalism was practised by the Aborigines. To some extent no doubt it was. Natives killed and ate little children, and the flesh of warriors slain in battle was sometimes eaten. Feasts on human flesh did not prevail as among the Fijians, but the natives seem to have eaten certain parts of the bodies of the slain in obedience to superstitious customs. Human life was rarely taken merely for purposes of nutrition, unless a tribe was starving. The Maori, who dwelt in a region better supplied with food, was a notorious cannibal. The natives of Fraser Island (Great Sandy Island), Queensland, feasted on human flesh; fat young men and women suited their palate. Long ago, tribes in parts of New South Wales (Bathurst, Goulburn, the Lachlan or Macquarie), in obedience to a religious ceremony, used to eat the first-born of every lubra. There is a well-authenticated case of a black fellow who had been thrown, when an infant, on the fire. He was rescued and brought up by some stockkeepers who chanced to pass. The scars caused by the burns were visible on him when a man, and his story was well known in the locality.

An Aboriginal's daily life was troublous, and he lived in fear of his foes. At times he dared not light a fire, lest it should guide his enemies to him. Often he himself had some wrong or fancied wrong to redress. Mayhap while the men were away at the chase the camp would be attacked. On their return the hunters would find the young women taken to be wives for their enemies and the old ones murdered.

Their domestic life was simplicity itself. A fire was enough, no cooking utensils were needed; there might be a wooden drinking bowl, and a large grass bag for holding food. The man also used a small grass bag for his private effects, these would consist of some round stones (Boolk or Bulk), to make his enemies sick; a packet wrapped in bark and painted with red ochre—the fat of some enemy he has slain; a few other odds and ends indicate an eye to business; round his middle is wrapped in many folds a cord spun from opossum fur, in which are stuck his hatchet, boomerang, and

throwing stick for small animals; in his hand he carries a variety of spears with different points, equally suited for war or the chase; a warm Kangaroo skin completes his equipment in the southern portion of the continent, but a cloak is rarely worn north of 29° south. Thus equipped, the fathers of a tribe stride forth, and at a respectful distance follow the women.

Each woman carries a long stick, the point of which has been hardened in the fire, and a child or two fixed in the mouth of her bag or upon her shoulders. A peep into the wife's great grass bag proves who caters for the family: a few roots and a stone to pound them with, a native bear's leg and a kangaroo's head, a few opossum skins if she is making a rug, and some shells to mark them with; an opossum's tail, to which are attached the sinews, also some kangaroo sinews: these are her sewing thread, more lasting than "Paisley's best;" native knives, a native hatchet, pipe clay, red ochre, yellow ochre, and paper bark to carry water in, tinder made of dried fungus, dried Banksia cones, and grease if she has been able to get it. Generally each woman carries a lighted firebrand in her hand. In the bag may also be a hand of some deceased friend or husband, kept in memory of one loved and lost.

The Australian Aborigine reminds the writer very much of the South African Bosjesman, who improves neither the land nor his own social condition; civilization merely exterminates him. He affects neither clothing nor fixed abode, his summer quarters are a few branches stuck in the ground to screen him from the wind. Both races are splendid huntsmen, stalking their game with unequalled cunning and perseverance. The Australian spears fish at night very expertly. He cooks his large game in ovens. A hole is made in the earth and lined with stones; fire is lit in it, and left until the stones are red-hot; the kangaroo or other meat is put in, and more hot stones are laid on the top; the whole is then covered with earth, and the confined steam and heat of the stones soon cook the meat. The river tribes are splendid swimmers, and catch ducks by diving underneath them and seizing them by the legs: an active swimmer will catch six or seven in rapid succession.

The Australian's weapons are numerous and differ in various districts. One is the club: it is only considered fair to strike at the head with this weapon. There are many forms of it, varying from ten to fifty ounces in weight. One is made with a sharp point, and

is thrown sometimes so that the point will wound; another is like a small wooden sword.

The fighting stick is made of hard pointed wood, and is a very dangerous weapon at close quarters. It is sometimes used for throwing at birds and small animals. The Tasmanians had a similar weapon.

In Queensland a heavy two-handed sword (Bittergan) is used, which is about three feet long, and very heavy. At Rockingham Bay a most formidable sword is found, 56 to 58 inches long, and weighing from 8 to 10 pounds. The men who wield it must be very powerful.

There is a great variety of war spears, the barbing of which, whether of stone or wood, is diabolically ingenious, and inflicts a terrible wound. They have also hunting and fishing spears. The Murray, Goulburn, and other river tribes, used reed spears. At one time the natives possessing land about Lancefield bartered greenstone for tomahawks or reed spears. On Mount William, near Lancefield, there was a large native quarry for this stone, which no doubt supplied a large extent of country.

Then there is the well-known spear-throwing stick, variously called Meera, Mero, Womerah, Gur-reek, Kurruk, etc.: it gives the spear thrower great leverage, and enables him to hurl with force and accuracy.

There are a number of leaf-shaped weapons used for throwing and for close quarters, some varieties of which resemble the boomerang, but have not its power of returning to the thrower. It may be that the peculiar powers of the boomerang were discovered by evolution from these leaf-shaped weapons. It varies very much in form, size, and weight. Two of the same pattern are rarely found, and the native alters a favourite weapon as experience suggests improvement. With a skilful thrower the furthest point of the curve is from a hundred to a hundred and fifty yards distant. A few can throw it, but not with accuracy, so as to strike an object behind them. Others throw it so as to run along the ground for a distance, hoop-fashion, then ascend, describe a curve, and come back to the thrower. Lieut. Breton says:—"I have seen a native throw one so as to make it go forty or fifty yards horizontally, and not more than three or four feet from the ground; it would then suddenly dart into the air to a height of fifty or sixty yards, describe a very considerable curve, and finally fall at his feet." A skilled warrior never fails to

make the boomerang come back. Sir John Lubbock gives a case in which a small prize was offered for every time the weapon was made to come back into a five-foot circle; although it was thrown with great force, the native succeeded five times out of twelve. There is also a war boomerang—Barngeet—which does not return to the thrower.

It has been proposed that the leaf of the white gum-tree suggested the boomerang. As the leaves of this tree fall to the ground they gyrate like the Wonguim, and if one is thrown straight forward it makes a curve and returns. Children play with these leaves, and an old man might make a wooden model, the peculiar movements of which would arouse curiosity, and lead to further experiments. A paper might be written on the boomerang alone; and perhaps no weapon has given rise to so much discussion. Mr. Bailey, once Vice-president of the Royal Society, remarked, "Its path through the air was enough to puzzle a mathematician. It resembles in appearance a weapon used by the ancient Egyptians for killing wild ducks, as represented on a tomb at Thebes. The centre of gravity is not in the weapon itself." Sir Thos. Mitchell discovered that the centre of the whirling motion might be found "in a line of equilibrium which should divide the surface acting on the air into three portions, in such manner as that the excentric portions should equal the central one." On attaching a centre to the boomerang he then found this was the centre of gravity, both during the rotary motion, and in a state of rest.

In the extreme north the bow and arrow are used. Varieties of the shield are found in use all through the continent. The stone implements made by the Australians are much superior in finish and shape to the rude flint implements found in the European drift, but time will not permit us to deal with them in detail.

The Aborigines frequently have considerable taste for carving and drawing. Some decorate their miamias with rude drawings, etched with a piece of pointed stone on sheets of bark which have been blackened in the fire. Red marks are found on the walls and roofs of many caves, as though a hand had been laid in some red ochre, and then pressed against the rock. Near these are generally seen other marks or drawings. These samples of primitive art have been seen in Eastern, Western, and Northern Australia, and on indurated sandstone on a cliff near the Goulburn river in New South Wales. There are some hand-prints and drawings of

animals in a granite cave near York, Western Australia, and in other places. The marks in the cave near York are quite indelible, and consist of hand, forearm, and finger marks; high up, and just over the mouth of the cave, is a circular figure painted with the same red substance, about fifteen inches in diameter, and filled up with lines and cross-bars. It must have been made by a person raised from the floor of the cave. The natives of the district could give no rational explanation as to the presence of these drawings.

A Mr. R. D. Hardie found the prints of five or six hands on some caves seventy miles east from the Avon river, in Western Australia, but could not make sure what colouring matter was used. Captain Flinders saw cave paintings on Chusan Island, Gulf of Carpentaria; there were porpoises, kangaroos, turtles, and a human hand, also a kangaroo with thirty-two people following it. Paintings have been seen on Clack's Island, off the north-east coast. On the north-west coast, in 1838, Grey and Lushington found caves with well drawn figures in different colours. Captain (now Sir George) Grey thought they had no connection with the red hands in the cavern near York. He thus describes one of the paintings:—"The principal painting in the cave was the figure of a man, ten feet six in length, clothed from the chin downwards in a red garment which reached to the wrists and ankles; beyond this red dress the feet and hands protruded, and were badly executed. The face and head of the figure were enveloped in a succession of circular bandages, or rollers, or what appeared to be painted to represent such; these were coloured red, yellow, and white; and the eyes were the only features represented on the face. Above the highest bandage or roller a series of lines were painted in red." There is no doubt this was an attempt to represent a fanciful head-dress which some tribes wear when dancing the corrobboree.

Captain Grey also found the profile of a human head cut in sandstone. The rock being hard, it must have been great labour for an Aboriginal to remove so much with his stone knife and hatchet. "The head," he says, "was two feet in length, and sixteen inches in breadth at the broadest part; and the depth of the profile increased gradually from the edges, where it was nothing, to the centre where it was an inch and a half; the ear was rather badly placed, but otherwise the whole of the work was good, and far superior to what a savage race could be supposed capable of executing."

There are numerous carvings on the headlands and flat rocks surrounding the harbour of Port Jackson, and at other parts of the coast, primitive in design, but highly interesting. At the north head there are many carvings and hand impressions on the sides of perpendicular rocks: in every case the subjects represented are indigenous—kangaroos, opossums, sharks, shields, boomerangs, and human figures in curvilinear attitudes.

The Barrier Range blacks are known to make rock-paintings of outstretched hands. These are executed in two ways, by daubing the hand with red ochre or pipe-clay, and printing it off, and by placing the hand on the rock, and squirting colour over it out of the mouth, so that when the hand is removed the outline of it is left on coloured ground. The young British schoolboy's primitive art occasionally decorates his companion's back with a long-eared illustration, printed off the hand.

Curiously enough vermilion impressions of human hands are found on the old Toltec buildings of Yucatan in Central America. In Borneo the stamp of a hand on a document is the sign manual of a native prince. The red colour is esteemed sacred in many instances by the inhabitants of a great portion of Asia.

Many blacks have unusual taste for drawing, and sketch with rapidity. Events worthy of note they record on their throwing sticks. The Hebrews wrote on sticks—"And the sticks whereon thou writest shall be in thine hand before their eyes." (Ezekiel xxxvii. 20.) And so did the early Greeks. Accounts, representing many a gallon of beer, even now are kept on sticks in some country places in England.

There is no doubt that long before Europeans had frequented the continent many Aboriginal tribes conveyed ideas by a kind of picture writing. Natives occasionally made pictures representing striking episodes in their lives. Near the tombs of warriors the Murray and Darling natives carved strange figures on trees, which would be intelligible to all the tribes in these areas. In Victoria a native artist carved a tomb-board for a Yarra Aborigine; strange to say it very much resembles the tomb-board of Wabojeeg, a celebrated war chief, who died on Lake Superior in 1793.

A native never betrays surprise or wonder at any strange or novel sight. An Aboriginal lad who saw the ocean for the first time, merely took one long glance seeking land on the other side, and remarked, "Big fellow water-hole that!" The perceptive powers of the Aboriginals are clear, and their faculties of

observation and imitation most marked. Like the Bosjesmen, they are excellent mimics, and show much original humour. Their chants are monotonous and harsh, and always in the minor key; still these poor blacks are not insusceptible of the powers of music. They have named all the conspicuous stars, every feature of the ground, every hill, swamp, bend of a river, etc., but not, in Western Australia, the river itself. "The water," a native laconically remarked, "runs away into the sea—it is no use naming that!"

The time is not far off when this strange race, and almost all record of it, will have disappeared. Even now, when travelling through the settled parts of the country, there are but few indications of the past presence of the natives to be seen. Two of these are—marks cut on trees, which will soon disappear, and the "Native ovens" or Mirnyongs. Sir Charles Lyell, when writing of similar mounds (Kjökenmoddings), found under the peat mosses of Denmark, composed of ashes, fine charcoal, fragments of bones, and other remains after cooking and eating, terms them "Kitchen refuse heaps." Mirnyongs are found in East and South-East Australia near lakes and lagoons, and in localities where fish, game, or food of any description was plentiful. Their positions were carefully selected, so that the occupants could command a view of the surrounding country without exposing themselves. When a company of natives returned from a hunt, the woman took a fresh supply of firewood and stones; thus in the course of centuries huge mounds arose. These ash heaps vary from ten to a hundred feet in diameter, and from a few inches to ten or twelve feet in height, depending on their age and on the number of persons frequenting them.

There are also some large shell mounds on the coast, especially near Cape Otway; the largest is a hundred yards long by fifteen to eighteen yards wide, and five or six yards high. It must have taken ages for the fish-eating coast tribes to build up such heaps. Unfortunately, the settlers have destroyed many mirnyongs by using them for manure. This is much to be regretted, as they are the oldest, and will be the most durable records of the purest and most homogeneous race of savages on the face of the earth. Latterly, some of the mirnyongs have been used by the natives as places of burial. Here and there on the basaltic plains of the western district of Victoria a stone mia-mia or shelter may be found.

Such, imperfectly, is a sketch of the Australian Aborigine and

[illegible]

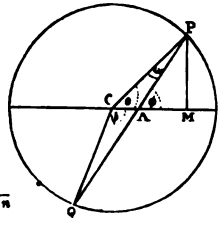
XIV.—*Note on a Class of Definite Integrals.*

By GEORGE A. GIBSON, M.A.

[Read before the Mathematical and Physical Section of the Society, 3rd February, 1887.]

THE integrals considered in the following note are of the class discussed by Poisson in the tenth volume of the "Journal de l'Ecole Polytechnique." Simpler proofs of them have been given by Mr. Walton in the "Quarterly Journal" for 1871, vol. XI., and by Mr. T. R. Terry in the "Proceedings of the London Mathematical Society," vol. XI. The proof I give puts the essential part of Mr. Walton's paper in a clearer light, besides generalising the integral; I also use Mr. Terry's transformation to prove Poisson's first relation, to which Mr. Terry himself does not refer. Mr. Terry observes that his proof is a "simple extension of the method used in the solution of one of Mr. Ferrers' questions in the 'Solutions of Cambridge Problems and Riders for 1878.'" I may add that the method referred to here is also to be found in Mr. Ferrers' "Spherical Harmonics" (p. 41).

Poisson proved that the integral $\int_0^\pi \frac{(\sin\theta)^m d\theta}{(1-2a\cos\theta+a^2)^n}$ is independent of a when $m=2n$, and is in general equal to $(1-a^2)^{1+m-2n}\int_0^\pi \frac{(\sin\theta)^m d\theta}{(1-2a\cos\theta+a^2)^{1+m-n}}$



a being less than unity and $m+1$ positive. It is clear that the integral has the same value for negative as for positive values of a, and that its value for $a>1$ can be deduced from that for $a<1$. I shall therefore suppose $a<1$ throughout.

Take a circle, centre C, radius unity; let A be a point within it, PAQ a chord through A, PM perpendicular to CA. Denote the angles ACP, ACQ, MAP, APC by θ, ψ, ϕ, ω respectively, and let $CA=a$, $AP=r$, $AQ=\rho$.

From the figure we see at once that

$$\frac{\sin\theta}{r}=\frac{\sin\omega}{a}=\frac{\sin\psi}{\rho}=\sin\phi, \quad \phi=\omega+\theta, \quad r\rho=1-a^2$$

$$r^2=1-2a\cos\theta+a^2;\ \rho^2=1-2a\cos\psi+a^2;\ d\theta=-\frac{r}{\rho}d\psi=-\frac{1-a^2}{\rho^2}d\psi$$

As θ increases from o to π, ψ decreases from π to o, ϕ increases from o to π, and ω goes from o to $\sin^{-1}a$ and back to o.

I. To show that $\int_o^\pi F\left(\frac{\sin\theta}{r}\right)d\theta = \int_o^\pi F(\sin\theta).d\theta$, where F denotes any function that is finite and continuous between the values o and π of θ. Substitute $\sin\phi$ for $\frac{\sin\theta}{r}$; hence

$$\int_o^\pi F\left(\frac{\sin\theta}{r}\right).d\theta = \int_o^\pi F(\sin\phi)d\theta = \int_o^\pi F(\sin\phi).d\phi - \int_o^o F\left(\frac{\sin\omega}{a}\right)d\omega$$

$$= \int_o^\pi F(\sin\phi).d\phi = \int_o^\pi F(\sin\theta)d\theta$$

since $\int_o^o F\left(\frac{\sin\omega}{a}\right)d\omega = o$

This theorem clearly includes the first case of Poisson's.

We may at once deduce the well-known theorem that $\int_o^\pi \log(1 - 2a\cos\theta + a^2)d\theta$ is zero when $a < 1$. Let $F\left(\frac{\sin\theta}{r}\right) = \log\frac{\sin\theta}{r}$

$$\therefore \int_o^\pi \log\left(\frac{\sin\theta}{r}\right)d\theta = \int_o^\pi \log(\sin\theta).d\theta$$

$$i.e. \int_o^\pi \log\,\sin\theta.d\theta - \int_o^\pi \log r\,d\theta = \int_o^\pi \log\,\sin\theta\,d\theta$$

$$i.e. \int_o^\pi \log r\,d\theta = o, \text{ as was to be proved.}$$

II. To show that $\int_o^\pi \frac{(\sin\theta)^m d\theta}{r^{2n}} = (1-a^2)^{1+m-2n}\int_o^\pi \frac{(\sin\theta)^m d\theta}{r^{2(1+m-n)}}$

Put for $\sin\theta$, r, $d\theta$ their values in terms of $\sin\psi$, ρ, $d\psi$, and we get

$$\int_o^\pi \frac{(\sin\theta)^m d\theta}{r^{2n}} = (1-a^2)^{1+m-2n}\int_o^\pi \frac{(\sin\psi)^m d\psi}{\rho^{2(1+m-n)}}$$

$$= (1-a^2)^{1+m-2n}\int_o^\pi \frac{(\sin\theta)^m d\theta}{r^{2(1+m-n)}}$$

The proof of this theorem by means of the angles ϕ, ω, though not very difficult, is a little troublesome.

Now denote the integral $\int_0^\pi \frac{(\sin\theta)^{2n}.d\theta}{r^{2n}}$ by I and put $r^2 = \Delta$; then by the theorem just proved, we have

$$I = (1-a^2)\int_0^\pi \frac{(\sin\theta)^{2n}.d\theta}{\Delta^{n+1}} = \int_0^\pi \frac{(\sin\theta)^{2n}}{\Delta^{n+1}}(\Delta + 2a\cos\theta - 2a^2)d\theta$$

$$= I + \int_0^\pi \frac{(\sin\theta)^{2n}}{\Delta^{n+1}}(2a\cos\theta - 2a^2)d\theta = I + K \text{ suppose.}$$

$$\therefore K = o. \quad \text{But } \frac{dI}{da} = \frac{n}{a}.K = o$$

Thus we see that when $m = 2n$ the integral is independent of A.

The proofs of Poisson's integrals which have just been given are very simple, especially when compared with Poisson's method. One feels a little surprised that Poisson did not try the result of substituting u for θ where $\frac{1+a}{1-a}.\tan\frac{\theta}{2} = \tan\frac{u}{2}$, in accordance with the ordinary method of integrating $\int \frac{d\theta}{1-2a\cos\theta+a^2}$. Jacobi ("Crelle," Bd. XV. p. 11) makes this transformation, giving the equations

$$\frac{\sin\theta}{\sin u} = \frac{1-a^2}{1+2a\cos u+a^2} = \frac{1-2a\cos\theta+a^2}{1-a^2},\ d\theta = \frac{1-a^2}{1+2a\cos u+a^2}.du$$

and practically gets the relation established in II. above.

Mr. Terry's paper is an extremely interesting one. I should also refer to Euler's "Theorema maxime memorabile circa formulam integralem $\int_0^\pi \frac{\cos\lambda\phi.d\phi}{(1-2a\cos\phi+a^2)^{n+1}}$" (Int. Cal., vol. IV.), and to Legendre (Exerc. tom. i. pp. 372–6).

XV.—*Some Minor Rights of Land-Ownership.* By ARCHIBALD FERGUSON, Writer, West Regent Street, Glasgow.

[Read before the Architectural Section, 14th February, 1887.]

WHEN I accepted the invitation of your Society a few weeks ago to furnish notes illustrative of the subject brought under your notice by the Royal Institute of British Architects, I expected to have been able easily to keep within very brief limits. As it has turned out, however—no doubt partly owing to the rather vague though suggestive title furnished by your Secretary, and partly owing to my desire, if possible, to touch on some cognate points which I was led to understand would be of interest,—the scope and plan of the paper have been gradually expanded until, I fear, the result may now be rather to perplex than enlighten a lay audience.

I may begin by stating that servitudes, in one sense, are not rights of ownership at all—ownership, bare and unqualified, is the negation of servitudes. Give to every owner of land his natural rights as such and you annihilate servitudes. For the most salient characteristic of ownership is that every owner has right to the exclusive use of his property; whereas a servitude is a right whereby two properties belonging to different owners are linked together in a mutual relationship, in virtue of which the owners of the one property, called the servient tenement, have their natural right to the exclusive use of their property restricted and qualified for the service and benefit of the other property and its owners; while the owners of the other property, called the dominant tenement, are invested with certain privileges over the servient tenement not naturally belonging to them, *qua* owners. Thus, in the servitude of way the dominant tenement and its owners enjoy a certain use of the servient tenement to which they are not naturally entitled, and from which the owners of the servient tenement would, but for the right-of-way, be entitled to debar them. Reinvest the owners of the servient tenement

with their full natural rights as owners, and you annihilate the servitude.

Again, in the servitude of light and air, the owners of the servient tenement are restrained from some of the uses to which, but for the servitude, they would naturally as owners be entitled to put the property, namely—from erecting buildings on their ground of such a character as to interfere with the lights of the dominant tenement; while, on the other hand, the owners of the dominant tenement are protected in the permanent enjoyment of light and air which, but for the servitude, would be precarious, and dependent upon the non-interference of the owners of the servient tenement. Reinstate each set of owners in their bare natural rights as owners, and again you annihilate the servitude.

But while in one sense servitudes are not rights of ownership, they are incidents of ownership. They are founded on it, and derived from it. Every owner has it in his right to create servitudes over his property at will, and that right belongs to him alone. No servitude can ever come into being without the consent, express or implied, of the servient owner; nor after being constituted can the servitude ever be extinguished without the consent, express or implied, of the dominant owner, for the element of perpetuity is one of the leading characteristics of all servitudes. A right of cutting timber, for example, has been denied the character of a servitude, because its permanence depends upon the industry of the servient proprietor in planting trees to take the place of the timber taken away; whereas a right to gather kelp weed from the sea-shore has been admitted a servitude, in respect that the perpetual supply of such weed is maintained by the sea and its tides without the aid of human industry.

Keeping in view, then, the fundamental principle that every servitude is founded upon the consent, express or implied, of the servient owner, the next question is—In what modes may that consent be given, so as to infer in law the constitution of a servitude?

The first and most obvious mode of constitution is *express grant*. Thus, two tenements originally formed part of one property. The owner, on selling one of them, may, in the disposition to the purchaser, have either reserved a servitude over the portion sold in favour of the portion retained, or, conversely, may have granted over the portion retained a servitude in favour of the portion sold. Or, again, the two tenements having been separate

prior to the constitution of the servitude, the owner of the servient tenement may, by agreement with the owner of the dominant tenement, or by unilateral deed, have given a written grant of servitude. By whichever of these modes of *express grant* the servitude is to be constituted, it is essential that the grant be in writing, and that it be holograph or tested. A verbal agreement will not do. If the grant be in writing as described, nothing further is required in the case of a negative servitude, such as a servitude of light. In the case of positive servitudes, however, the writing will not of itself suffice until it has been followed either by possession of the servitude, or by registration of the writing in the Register of Sasines.

This division of servitudes into positive and negative demands here a word of explanation. A positive servitude is one, the exercise of which by the dominant owner involves a state of matters on the servient tenement which the owner of the latter would, but for the servitude, be entitled to interdict or alter, by an action at law against the owner of the dominant tenement. Of positive servitudes we have good examples in the right-of-way and in the right to drain one tenement through another. The exercise of these and similar servitudes involves a positive encroachment or intrusion upon the servient tenement, and our law distinguishes them as positive servitudes. Other servitudes there are, however—the servitude of lights, for example,—which involve no such intrusion or encroachment on the servient tenement, and these are called negative servitudes. In their enjoyment the dominant owner does nothing he might not do independently of any servitude, or which could subject him to an interdict or other action at the instance of the servient owner. Thus, in the servitude of light the owner of one tenement builds, we shall say, up to the boundary of his property, and leaves a window in the wall overlooking the adjoining tenement. All this he is perfectly entitled to do, and frequently does, without any servitude and without asking or obtaining the consent of the servient owner. He is in no way intruding upon or interfering with the servient tenement. The very light and air, which are the subject of the servitude, can in no true sense be said to be drawn from the servient tenement. They do not diminish the supply available to the servient tenement. They are simply the light and air, or part of them, which the dominant tenement would have enjoyed although its owner had never built at all. What, then, is the

essence of this negative servitude to the dominant owner? Simply this, it invests him with a right to restrain the servient owner from interfering with the lights in question.

I have already stated that an *express grant* of a positive servitude is inchoate and incomplete until it has been intimated to the public and all concerned, either by registration in the Register of Sasines or by overt possession and exercise of the the servitude by the dominant owner. The rule is different in the case of negative servitudes. In these *express grant* is sufficient in itself. Not only is the servitude which it creates of such a character as obviously to be in the general case incapable of overt possession, but the grant itself does not require to be recorded in the Register of Sasines. Therefore a negative servitude which was originally contained in the titles of the servient tenement was in nowise impaired by having disappeared from them for 40 years, there having been no contrary possession by the servient owner and no prescription of immunity. This, undoubtedly, is an anomaly in our law, and I believe it would be for the public advantage if the rule were altered, and grants of negative servitudes were incomplete and ineffectual until recorded.

Failing *express grant*, the next mode of constituting servitudes is by *implied grant*. The Courts appear to have been slow to admit *implied grant* as a mode of constituting servitudes; at last, however, they did admit it for positive servitudes. Since then our writers have generally agreed in maintaining that implied grant, though competent in the case of positive servitudes, was inapplicable and incompetent in the case of negative servitudes. Lately, however, as we shall see, the Court of Session has apparently been disposed to admit implied grant as a mode of constitution even for the servitude of light and air.

The only circumstances in which *implied grant* has been recognized as a mode of constituting servitudes are where the dominant and servient tenements have originally belonged to one proprietor, who subsequently either conveyed away the dominant tenement, retaining the servient tenement, or conveyed away both tenements simultaneously to different individuals, and where at the date of the disposition of the dominant tenement the servitude in question was absolutely essential to its enjoyment, or at least was necessary to its fair, convenient, and comfortable enjoyment.

There does not appear ever to have been much dispute regarding cases where, in the above circumstances, the servitude in question

was absolutely essential to the enjoyment of the dominant tenement. The owner of an estate, for example, who has conveyed away the minerals, reserving the surface, might be compelled to give the granter an access to the minerals although the conveyance were silent on the point. For the granter to refuse such an access would be not merely to derogate from, but practically to nullify, his own grant. Or if the same owner were to sell a house situate in the middle of his estate he might, without any express stipulation in the disposition, be compelled to provide the purchaser with an access to and from the house and the nearest highway. Such an access is termed a way of necessity. It is hardly a servitude right. It might almost more correctly be called a part and pertinent of the subject conveyed, and the rule of law applicable to this branch of our subject is obviously supported by every consideration of equity and common sense.

An illustration of the principle will be found in a case decided last year, namely—The Union Heritable Securities Company, Limited, against Mather, 3rd March, 1886, 13 Ret. 670. This case referred to a block of buildings at Gorbals Cross, Glasgow. The tenements are built in a square, the fronts facing Main Street, Gorbals Cross, Govan Street, and Muirhead Street, while the background forms a common square. The block was built in two lots, A and B. Through B, as originally constructed, ran a pend which was used by all the inhabitants of the buildings, and especially by the tenants of lot A as a cart entrance to bring in flour to their bakery. After some years the disponee of lot B attempted to shut up the pend although no other entrance of the same nature and value to lot A could be made, except by destroying part of lot A to make a new pend. The Court held that as the pend had been made originally for the use of the inhabitants of the whole square, and especially for the convenience of lot A, and had been so used, there was a way of necessity through the pend which the proprietor of lot B could not shut up.

It is, therefore, a well-established rule that where the proprietor of an estate has conveyed away a portion of it, to the enjoyment of which a particular servitude over the remainder of the estate is absolutely essential, that servitude will be implied by law although not expressed in the conveyance. The mere granting of the conveyance is sufficient in law to infer the consent of the granter to whatever servitudes may be absolutely necessary to give proper effect to the conveyance.

But cases might occur where a particular servitude, while not absolutely essential to the grantee's enjoyment of the portion of the estate conveyed to him, might yet be necessary to the fair, convenient, and comfortable enjoyment of it.

To such cases the principle of implied grant was extended in Cochranes *v.* Ewart, 13th Jan., 1860. 22 D. 358. Affirmed 25th March, 1861, 23 D. (H. of L.) 3. Here two adjoining feus at Newton-Stewart came to be the property of one man. The one feu was occupied as a tanyard, the other as a garden. The proprietor constructed in the garden a drain and cesspool for the accommodation of the tanyard. Some time afterwards he sold the tanyard, and the purchaser continued for years to use the drain and cesspool. Subsequently the garden was sold to Ewart, who stopped up the drain, whereupon this action was brought to have him ordained to restore the drain, and to have it declared that the garden was bound to receive, as hitherto, the water flowing from the tanyard. None of the titles made any allusion to, or threw any light on, the question. Lord Neaves (Ordinary) assoilzied the defender, but his judgment was recalled by the First Division, who declared in terms of the conclusions of the summons. Lord Deas, who delivered the judgment of the Court, observed that, besides express grant and prescription, there were three ways in which such a servitude might be constituted: (1) If it can be shown that the water follows the natural declivity of the ground; (2) if there can be held to be in the dispositions an implied grant; and (3) *rebus ipsis et factis*, if the actings of the parties fairly imply and recognize the existence of the right. This judgment was affirmed on appeal to the House of Lords. Lord Campbell, however, with whom the other judges concurred, observed that the judgment proceeded upon the principle of implied grant alone, constitution of a servitude *rebus ipsis et factis* being unknown in law, and this not being a natural servitude.

Attempts have been made to extend the principle of implied grant to cases where the two properties having belonged orginally to one proprietor, the alleged servient tenement was on severance disponed first in order. Thus, in an American case, Pyer *v.* Carter, 21st Feb., 1857, 1 H. & U. 916, the owner of two villas caused the sewage of one of them to be carried off by a drain running under the floor of the other, which, for convenience sake, we may call the servient villa. Thereafter he sold the other also. The conveyance

made no reference to the drain. The Court held that, in these circumstances, a servitude of drainage had been constituted over the servient tenement by implied grant.

The authority of this case has never been accepted in this country, and it is now conclusively settled by the English case, Wheeldon *v.* Burrows, 17th June, 1879, 17 S. R., C. D. 31, that if the common proprietor intends to reserve any right over the tenement first conveyed away by him it is his duty to reserve it expressly in the conveyance.

The question whether the principle of implied grant should apply to negative servitudes was decided in the affirmative in the case Heron *v.* Gray, 27th Nov., 1880, 8 Ret. 155. To state the circumstances of this case shortly, but with practical accuracy:—The National Heritable Company were proprietors of the house and garden, No. 1 Arniston Place, Edinburgh. The lower flat of the house—the windows of which looked out upon the garden—they sold to Heron. The conveyance contained no express servitude of light in favour of the granter. Subsequently the company sold the garden and the upper flat of the house to Gray—the conveyance in Gray's favour expressly declaring that there was no restriction against building on, and no right of servitude affecting, the garden ground. Heron claimed a servitude of light and air in virtue of implied grant, and Gray, with the view of testing the question, erected a wooden screen against Heron's windows, so as to block them. The action was thereupon raised in the Sheriff Court. The Sheriff held that there was no servitude; but, on appealing to the Second Division, this judgment was reversed, the Court finding that there was an implied servitude of light, and that the defender Gray was not entitled to cut off that light.

The soundness of this decision has been a good deal canvassed, although, as I think, on insufficient grounds, and it seems not only to be consistent with the general rule applicable to flatted houses, namely—that the proprietor of the street flat and solum is not entitled to interfere with the lights of the upper flats, and *vice versa*, but it also seems to receive considerable support from the more recent case, The Commissioners of Supply of Argyleshire *v.* Campbell, 10th July, 1885, 12 Ret. 1255. The pursuers in this case had feued from Macfie of Airds in 1863, a plot of ground in Oban for their Court-Houses and County Buildings. The ground was described in the charter as bounded on the north by a private lane belonging to the superior. It was an express condition of the feu that

within three years the proposed buildings should be erected in conformity with plans to be submitted and approved of by the superior. The charter gave the Commissioners no servitude of light or access over the lane. The plans, however, submitted to the superior in terms of the charter as already quoted, showed not only an entrance from the main street, but also a door of access from the lane, and a large window looking into the lane. This was not objected to by the superior; and buildings were erected in conformity with the plans. Fourteen years later the superior feued the adjoining ground, including the aforesaid private lane, to Doctor Campbell, of Oban. The feu charter in Campbell's favour specially excepted and reserved the rights of the public, and reserved "also to the adjoining feuars their rights of access by the lanes, and the whole rights and privileges which they at present possess in connection with the subjects above disponed." The clause of warrandice declared that "this warrandice shall apply to the solum of said lanes only in so far as the rights of the public and the adjoining feuars are not thereby prejudiced, which rights are specially reserved." Campbell proposed to build over the lane, leaving a pend for access to it. The Court granted interdict of these proceedings on the ground that the Commissioners had established a servitude of light as well as of access over the lane, and that their light, though not their access, would be injuriously affected. The position of those who would question the authority of Heron *v.* Gray is that a negative servitude cannot be constituted except by express grant. The reservation, however, in Doctor Campbell's titles cannot be called an express grant. That reservation never mentions a servitude of light. It simply reserves to the adjoining feuars their previously-existing rights. The superior's acquiescence in the Court-Houses plan cannot be called an express grant—such a plea seems to have been rejected in Blair *v.* Dundas, 12th March, 1886, *infra*,—and, finally, there was no express grant in the Commissioners' title. We must, therefore, hold that the judgment in the Oban case recognised in effect the doctrine of implied grant as applicable to negative servitudes, and this seems consistent with reason and equity. For, if equity demands in certain circumstances the implication of a servitude of way or drainage, it must in the same circumstances equally demand the implication of a servitude of light, if that servitude be no less essential to the fair enjoyment of the dominant tenement.

The only other way of constituting servitudes according to the

law of Scotland is by *prescription*, and this mode is applicable only to positive servitudes. A negative servitude, such as the servitude of light, cannot be constituted by prescription.

Prescription is a doctrine which was familiar to the Romans, and which has been adopted into every subsequent system of jurisprudence. It results from the connection between ownership and possession, and it is grounded on abandonment or acquiescence. The period of prescription is arbitrary, and varies in different countries. In England the period appears to be twenty years. In Scotland, till recently, forty years was the prescriptive period, and though, by the Conveyancing Act of 1874, the period was shortened to twenty years for general purposes, it still remains forty years so far as regards servitudes. Thus, where a proprietor has for forty years permitted the use of a road over his property to an adjoining proprietor, the law will presume a servitude or right-of-way in favour of the latter, although there be no other grant, express or implied; and this presumption will not be overcome by the fact that the road has been used in the face of a notice forbidding trespassers. The same rule will apply to all other positive servitudes. There is in all such cases direct acquiescence in, and consent to, the servitude on the part of the servient owner. At any time during the forty years he could have interrupted the servitude by an action of interdict; and there could be no stronger proof of his acquiescence in the servitude than the fact that no such action has been taken.

In England, as we are informed in the communication from the Institute, prescription applies to negative servitudes in the same way as to positive servitudes.

This in Scotland is regarded as a total misapplication of prescription. The circumstances of a negative servitude afford no ground for inferring acquiescence on the part of the servient owner. Take, for example, the servitude of light. When an owner builds his house on his own property, but with windows overlooking his neighbour's property and deriving light from it, he does not obtain his neighbour's consent. No such consent is required. There is no encroachment on, or intrusion into, the neighbour's property, and the neighbour himself has no legal ground of complaint, or action at law, against anything that has been done. Neither does the neighbour abandon his own property. On the contrary, during the period of prescription he remains in full possession of his property, discharging every duty

and right legally incumbent on him as owner, whether to the public or their adjoining proprietors. The builder, on the other hand, during the prescriptive period has possession of nothing but his own property. In particular, and by hypothesis, the builder has during the course of the prescriptive period no right, express or implied, to restrain his neighbour from building so as to interfere with the lights in question. But this right, and this alone, constitutes the servitude of lights. The result of the English rule is that it applies the principle of prescription to cases where there has been no possession during the prescriptive period on the part of the dominant owner, and it deprives owners of their rights of property in circumstances which make it involve meaningless confiscation.

In Scotland, therefore, we regard the English rule as unsound in principle, and immemorial authority has established in Scotland the rule that no negative servitude can be established by prescription. I need not quote any case in support of so familiar a proposition, but, for the purpose of illustration, I may refer to a recent case where that principle guided the decision of the Court. The case I refer to is Blair *v.* Dundas, 12th March, 1886, 13 Ret., 759. The Edinburgh Assembly Rooms were built in 1786 on part of the extended royalty of the city of Edinburgh, then being feued out by the magistrates. The charter to the trustees was granted three years later, namely, in 1789. The buildings covered the whole feu except passages at either side of the buildings, which passages were used for carriages, &c. After the Assembly Rooms had been built, but before the Trustees had obtained their charter, the Magistrates feued the adjoining stance to John Brough, wright. His charter was dated 1787, and described his feu as bounded "on the west by the east passage into the Assembly Rooms." Shortly before the date of this charter, Brough had erected upon this stance a four-storeyed tenement with certain of its windows looking into the space left vacant as a passage at the side of the Assembly Rooms. No right of servitude in favour of Brough appeared either in his charter or in that of the Assembly Rooms. In 1863 Robert Blair, being then proprietor of the stance feued by Brough, obtained warrant from the Dean of Guild for certain alterations which, *inter alia*, involved making a new window looking into the passage. The plan was submitted to the directors of the Assembly Rooms, and their secretary, Mr. Stewart, endorsed it—

"We agree to the alterations proposed—For the directors of the Assembly Rooms, John Stewart, Secy." In 1885 the Trustees of the Assembly Rooms proposed to close up the passage before referred to, and to make certain alterations on their property, which would have had the effect of blocking up five of Blair's windows. Blair brought the matter into Court, alleging, in addition to the facts already stated, that, in accordance with a resolution of 1782 that the plans should be approved of before a feu was granted, the plans of both properties had been exhibited to, and approved of by, the Town Council, before the granting of the respective charters, and formed a condition of the granting of the feu charters, and that Brough's feu was granted prior to that of the Assembly Rooms. At this time Blair and his predecessors had enjoyed the light for 100 years. The Court, after a proof, held that Blair had failed to prove any implied grant of servitude, and that the alleged servitude of lights being of a negative character, could not be acquired by prescription. The Court therefore refused Blair's appeal.

Very similar to rights of servitude are those rights connected with mutual gables, and with that class of tenement property the several flats of which are owned by different proprietors. The late Lord Jeffrey regarded the builder of a mutual gable "as sole proprietor of the gable with a kind of conventional servitude provided in favour of the party who comes to build on the adjoining stance to have right to one-half on paying the party who built it, or the party to whom he may have conveyed it." Hunter *v.* Luke, 8 D., 790. On the other hand, the rights to support and to light and air possessed by the proprietors of the upper flats of a tenement, as against the lower proprietors, may, from their resemblance to the *servitus oneris ferendi* and the *servitus luminum*, be taken as illustrations of how closely the law of tenements is allied to the law of servitudes. A reference therefore to those two subjects, namely—Mutual Gables and the Law of Tenement, may perhaps be regarded as not out of place in the present paper.

The mutual gable common amongst ourselves is an equally familiar object in the towns of the Continent and of the United States. It was well known to the Romans, and from them much of our law on the subject is derived.

Strictly speaking a mutual gable is not a gable. A gable is the end outside wall of a building. A mutual gable, on the other hand, is simply the division wall between two tenements, and as

such it ought to contain the vents, presses, and other conveniences required in such division walls. When the two tenements are erected at different times, this division wall requires to serve temporarily as a gable to the tenement first built. Such, however, is not its ultimate purpose. It is not a gable. It is an inside or division wall. It is a part of the tenement second erected quite as much as it is a part of the tenement first erected. In other words, before the second proprietor comes to erect his tenement, this part of the work—namely, the division wall—is done for him by his neighbour, and the consequence is that when the second proprietor erects his tenement and uses that wall, he is compelled to pay his share of the cost. As the mutual gable belongs to both tenements, it ought to be built on the boundary line betwixt the two feus, one half of its thickness being on either side of the line. This, obviously, is no encroachment on the second feu. On the contrary, there would be an encroachment on the first feu if the entire gable were built upon that feu.

The question of how far the builder of the first tenement is entitled to erect a mutual gable without the consent, express or implied, of his neighbour, was considered in Begg *v.* Jack, 10th Jan., 1874, 1 Ret. 366. There the proprietor of a suburban piece of ground took down the whole garden wall which formed the boundary of his property, and on its site erected the mutual gable of a four-storey tenement then in course of erection by him on his property. This was done not only without the consent of the adjoining proprietor, but actually whilst negotiations were going on as to the terms on which he would give consent. These negotiations fell through, whereupon the adjoining proprietor applied to the Court to remove the gable and restore the garden wall, or alternatively for damages. In delivering judgment, Lord Gifford stated that in his view "in rural subjects when the lands of the parties are divided by mutual fences, whether walls or hedges, the proprietor of one of the subjects has no right, without his neighbour's consent, to remove these fences, and insist upon erecting a gable, one half upon his neighbour's property. In like manner, where, even in a street, a church has been built entirely within its own ground, I do not think adjoining proprietors, apart from contract, express or implied, can insist upon building the gables of their houses one half upon ground belonging to the church, although the church and its proprietors can never take benefit from such gables as mutual gables." The Court, in the special

circumstances of this case, did not order the removal of the mutual gable, but they deprived the builder of the gable of his claim for half its value, and authorised the adjoining proprietor whose ground had been unwarrantably encroached upon to use the gable without payment of any part of its cost. Thus, the builder of the tenement got off very easily. But in the subsequent case, Graham *v.* The Kirkcaldy Magistrates, 26th July, 1882, 9 Ret. H. L. 91-92, indications were not awanting to show that had Jack's case gone to the House of Lords the gable would have been taken down.

The only qualification of the rule established by these cases is that the consent of the neighbouring proprietor may be inferred from circumstances, and is implied by the custom of all burghs. Lamont *v.* Cumming (*vide infra*).

One of the leading cases in regard to common gables is that of Law *v.* Monteith, 30th Nov., 1855, 18 D. 125. Hutchison & Son, timber merchants in Glasgow, owned two steadings on the north side of Garscadden Street, one of which they sold to Lorimer & M'Gowan, retaining the other. Lorimer & M'Gowan, on their steading, erected a tenement with mutual gable adjoining the stance retained by Hutchison & Son. Thereafter the tenement was sold by Hutchison & Son to David Law. The latter proceeded to erect a tenement on his stance, whereupon Monteith's trustees claimed from him the half expense of the mutual gable. The case came into Court, and the following points were decided :—

(1.) The original builder was entitled to pass over the boundary without encroachment.

(2.) The right to claim half the expense of the gable required no express agreement but inhered in the subjects.

(3.) Being a real right, the claim was available to, and against, singular successors.

(4.) Though the claim came into existence with the original building of the gable, it only emerged as an active claim for payment when the adjacent site actually came to be built upon and the gable appropriated.

Supposing the gable to be built between two stances, both of which belong to the builder of the gable, who sells the occupied stance, and proceeds to build upon the vacant stance and to use the gable, the claim for half the value of the gable will be good against him in the same way as if he were a stranger The Glasgow

Royal Infirmary *v.* Wyllie, 15th June, 1877, 4 Ret., 894. The defenders in this case were the Trustees of the Baptist Chapel in Cambridge Street, Glasgow. The pursuers (the Infirmary) were the proprietors of the tenement adjoining the chapel. The two stances on which the properties were built had at one time both belonged to the same proprietor, Sharp, who built the Infirmary's tenement with a mutual gable betwixt it and the other subject, and then conveyed it to the Infirmary's author. Subsequently Sharp sold the adjoining ground to the party who sold it to the Baptist congregation. The latter had occupied the ground with temporary erections, namely—two sheds and a one-storey stable, with a flue against the mutual gable. When the chapel began to be built the Infirmary put in a claim for half the mutual gable. The claim was resisted, but the Court sustained it, notwithstanding the temporary use which had previously been made of the gable, and notwithstanding the circumstance of the gable having been built by Sharp before severance of the two properties.

In Sinclair *v.* Brown Brothers, 17th Oct., 1882, 10 Ret. 45, temporary buildings whose roof rested wholly upon pillars, and which only touched the gable by a rhone in front, were held not to subject the proprietor to liability for the gable.

This case also illustrates how the second proprietor may be called on sometimes to pay his share of the gable even before he begins to build. Of two stances, the eastmost was given off first to Sinclair, who, by his feu contract, was bound to build with a mutual gable between his stance and the other, with right of recourse against his neighbour for half the cost. Nothing was said in the feu contract as to the date when the claim was to emerge. The other stance was feued by Brown, whose feu contract referred to this mutual gable as already built, and bound him to pay half the cost, nothing being said of the date of payment. The Court held that by the terms of the feu contracts the second feuar was bound to pay for the gable whether he used it or not, and therefore that the amount became payable at the date of the second feu contract.

A somewhat kindred case was that of Ness *v.* Ferries, May 13, 1825, 4 S. 7. By the feuing condition of the property of Drumsheugh, Edinburgh, it was stipulated that the feuar, upon building his house with a mutual gable, should have recourse against the feuar of the lot adjoining such mutual gable, so soon as the same should be feued, for half the expense thereof, according to the

valuation of the pursuer's architect. By the plan the houses in the centre and at each end of the street were to be higher than those adjacent to them. Ness feued one of the centre stances, and built thereon a house four storeys high. Ferries feued the adjoining stance, and built thereon a house which was only three storeys high. The Court found Ness entitled to half the value of the gable of four storeys. This decision, however, was come to solely upon the terms of the feu contract. The custom of Edinburgh was alleged and apparently admitted to be that mutual gables were paid for according to the extent of the mutual possession, and there seems no doubt that but for the special terms of the feu contract Ferries would have been held not liable for the half of the gable beyond three storeys.

Coming to the amount to be paid for the use of the mutual gable, cases are frequent where, as in Sinclair *v.* Brown Brothers and Ness *v.* Ferries, both before mentioned, the amount is regulated by the parties' titles. In both of the cases I have just referred to the amount was assessed at half the original cost of the gable.

A corollary from what I have said as to the nature of the mutual gable would seem to be, that in cases at least where the second proprietor is bound for half the original cost, the builder of the mutual gable is bound to erect it in a reasonable and usual and tradesmanlike manner, and with a due regard to the convenience and probable plans of his neighbour. Mutual advantage and economy are the basis of the whole arrangement, and if, through any disregard of the rules referred to, unnecessary expense is occasioned to the second proprietor, that expense ought to be borne by the party occasioning it. This was not decided in the case Lamont *v.* Cumming, yet to be referred to, but it is quite in accordance with the opinions delivered by the judges in that case.

It should here be remarked that half the cost of the gable must always mean, not necessarily the actual cost, but rather the sum which competent men valuing the gable would assess as the fair proportion to be paid by the second proprietor. In other words, "cost" for this purpose is synonymous with "value," the second builder having nothing to do with any exceptional cost which the first builder may have been committed to by his extravagance, folly, or misfortune. The second builder, for example, has no concern with any extra expense which the first builder may have incurred in re-erecting a portion of the gable blown down by a

hurricane during its erection, or destroyed by fire after its completion but prior to the date of his (the second proprietor) taking possession of it.

Seeing, then, that the builder of the gable is subject to the sole liability connected with risks such as these during the period between the date when the gable is built and the date when it comes to be used for the second tenement, it may be, and often is, inquired whether he undertakes also the risks of a fall or rise in building prices and gable values during the same period. In other words, is the cost (*i.e.*, the value) of the gable to be taken as at the date of its being built or as at the date when it falls to be paid for by the second proprietor? I have little doubt that the latter alternative contains the true answer. In short, the builder of the gable remains sole owner of the same until it comes to be actually used or paid for by his neighbour. Until then he has the sole risk and control of the gable, and he may repair, alter, or demolish it at pleasure. The transaction between him and the adjoining proprietor, therefore, when the gable comes to be used for the second tenement, is practically a sale; the amount to be paid is the price, and the price ought to be the value as at the date of the sale. This view of the matter is quite consistent with the legal authorities, and it is in harmony with the rule which makes each proprietor liable (unless in special cases) only for that portion of the gable which he actually uses. Ness *v.* Ferries *(supra)*. It accords also with what I believe has been for many years the general custom in Glasgow, although there is one case which appears to lend support to the opposite view. I refer to The Glasgow Royal Infirmary *v.* Wyllie *(supra)*. In that case, which originated in our local Sheriff Court, but afterwards was carried to the Court of Session, the late Sheriff Clark seems to have held incidentally that the amount to be paid for the use of the gable was half the original cost of the gable, and that the original cost was to be rated at two-thirds of the present value. The learned Sheriff's judgment was upheld in the Court of Session, but I do not find that this particular point was made the subject of argument before their Lordships.

Whether or not the view I have taken in regard to this be the correct one, I would suggest that much would be done towards a final settlement of the question for Glasgow and district, were this Society to collect evidence as to the custom of the district and record the result of their investigation, along with a resolution that

the custom as so ascertained should be recognised and formally adopted by the Society.

The mutual gable is the common property of the proprietors of the two tenements to which it belongs. Two leading rules in regard to common property in general are: (1) In the control or management of the property no co-owner is entitled to overbear or ignore the resistance of the other; and (2) no co-owner can be compelled to continue the community against his will. Each owner has thus, however small his interest, an absolute veto upon any proposed innovation, and that without assigning either reason or interest for his action. To relieve, however, the dead-lock between co-owners, which in numberless cases this rule would bring about, the second rule has been established, giving to each owner an absolute right at any time to demand a division of the subject (if it be divisible), or a sale, followed by division of the price (if it be not). One peculiarity of the mutual gable is that it is beyond the reach of this remedy of compulsory division or sale. It is incapable of division, and the only way to sell it would be to sell the tenements of which it forms part. Besides this, the very nature of a common gable obviously infers a tacit agreement between its owners that, notwithstanding their common ownership, each owner is to have the exclusive use and control of his own side of the gable so long as he does not affect the stability of the erection or interfere with his neighbour's convenience and comfort. These considerations show that the veto applicable to the ordinary case of common property can only be applicable in a limited degree to common gables. Of these there are illustrations in the law reports. The case of Allan & Co. *v.* Glasgow Union Railway *(Winter Session, 1876-7)*, referred to a prominent gable in St. Enoch Square, and established that without Allan & Co.'s consent the Railway Company were entitled to use their own side of the gable for painting up business notices and advertisements.

Lamont *v.* Cumming, 11th June, 1875, 2 Ret. 784, was a case from Renfrew in which the builder of the second tenement, finding that the mutual gable contained neither fireplaces, vents, nor other usual conveniences, was found entitled to insert joists, to convert a recess into a fireplace, slap out a vent, and raise the height of the gable from three storeys to four. The pursuer, who was the owner of the first tenement, objected to these proceedings, and pleaded the right of veto applicable to common property; but the judges of the First Division declined to entertain the plea, and refused to interfere

with the operations referred to, reserving to "the pursuer any pecuniary claim competent to him against the defender in respect of his making use of the said gable." The sequel of the case does not appear in the reports, but I have no doubt, in adjusting the amount of this claim, the expense of the operations just mentioned would be allowed, so far as extraordinary, as an abatement in favour of the defender.

We have up to this point been considering mutual gables with reference to the ordinary case where each tenement is owned, not in flats, but as a whole. The rules on the subject have been thought to become a little more complex when one or both tenements are owned in flats, one proprietor or set of proprietors owning the ground floor, another the floor above, and so on up to the roof. In such tenements the principles of common property have been found insufficient to regulate the rights of the proprietors *inter se*. Accordingly, our law has recognised a principle which it has called common interest; and one of the chief divergences between the effect of common property and common interest is this, that the veto which I have already explained as arising from co-ownership is, in cases of common interest, not competent unless the party objecting can show that his neighbour's operations are injurious or likely to be injurious to him. I think, however, that while this distinction is of great importance in regard to some questions, it is of little importance so far as mutual or common gables are concerned. These, as we have already seen, are not affected by the veto of co-ownership to the same extent as most other common property. It is difficult, if not impossible, to say whether, apart from the terms of the titles, the gables and mutual gables (containing vents, &c.) of flatted tenements are held in common or severally by the proprietors interested. But in either case it seems clear enough that the right of the several proprietors in such gables will be regulated by practically the same rules as regulate the use of other gables. The only case, therefore, to which it is necessary here to refer is Gellatly *v.* Arrol, 13th March, 1863, 1 Macp. 592. Here the owner of the upper flats of three contiguous tenements proposed to open communication between his flats of the two end tenements and his flats in the middle tenement by slapping out a door in either gable of the latter. One or both of these vents interfered with the vents of the lower heritor. The Court ordered the doors to be built up, and the vents restored to their former condition.

In the case of adjoining tenements owned in the ordinary way the mutual gable is the only point of contact between the two properties, but in tenements owned in flats or other subdivisions, the points of contact between the several properties are multiplied, and in partition walls and mutual floor-ceilings we find mutual rights of ownership so closely resembling and, as I think, so strictly analogous to those we have been discussing in the case of mutual gables, that it is perhaps unnecessary further to refer to them in detail. Suffice it, therefore, generally of such partitions, mutual floor-ceilings, &c., to say that, as in the case of mutual gables, so in their case (and *vice versa*) the rule may be accepted that each owner is obliged to avoid injuring the subject himself, and to look after the preservation of it with the same care as if it were his sole property; and further, that he is entitled to prevent anything being done by a co-proprietor which goes beyond that proprietor's rights, and that so far as is consistent with the safe and comfortable enjoyment of the subject for its primary purposes by the other proprietors interested, each proprietor is entitled to the sole control of his own side of the partition or floor-ceiling, and this not so much on the principle of common interest as on the principle of common property, coupled with the peculiar character of the subject itself.

Two cases may be mentioned in illustration of alterations which have been prohibited on mutual floor-ceilings, the one case being Walker *v.* Braidwood, 1797, Hume 512, where a proprietor was interdicted by his neighbours from cutting away any part of the joisting so as to weaken the barrier; and the other case being Gray *v.* Greig, 18th June, 1825, 4 Sh. 104, where a proprietor was prevented from endangering the floor-ceiling by removing a bearing partition from below it. Similarly, neither proprietor will be entitled to carry out any operation which, by increasing the risk of fire or otherwise, may endanger his neighbours. This, however, of course, is a general proposition not confined to floor-ceilings.

Passing from mutual gables, floor-ceilings, &c., to the common passage and stair of the tenement, these have been held to be the common property of the proprietors served by them, and of such proprietors alone. This appears to have been the ground of judgment in Anderson *v.* Dalrymple, 1799, M. 12,831. In that case Dalrymple and others were proprietors of the two upper storeys of a house in Princes Street, Edinburgh, of which the

sunk storey and that above it belonged to Anderson. The two upper storeys entered by a stair near the inner extremity of a common passage, at the same extremity of which, too, was the street entry to Anderson's property. Anderson having converted a front room of his house into a shop, proposed to strike out a door to it from the passage. This was objected to by Dalrymple. The Court were satisfied that the latter could not be hurt by the alterations objected to. Nevertheless, the opinion of the Court was, that as Dalrymple had a right of common property in the passage, and not merely a servitude *oneris ferendi* on the wall, no alteration whatever could be made on it without his consent. Precisely the same question occurred again in Reid *v.* Nicol, 1799, M. app. No. 1, when Anderson's case was reconsidered, and the judges adopted the principle of that decision, and on that ground—namely, that the passage was common property—refused to allow the proposed alterations.

In connection with the common passage and stair we have several cases which, although not exactly relevant in support of the proposition that the passage and stair belong solely to the proprietors who are intended to be served by them, will illustrate the principle that a right of common interest will only warrant objection to proposed operations which prejudicially affect that interest; whereas (in the general case apart from gables, &c.) a right of common property confers on each owner an absolute right of veto, irrespective of the harmlessness of the operation.

In the case of Ritchie *v.* Purdie, 21st June, 1833, 11 S. 771, two contiguous tenements adjoining the East-End Assembly Rooms, Edinburgh, and consisting each of several storeys, had one entry from the street and one staircase in common, both of which were within one of the tenements, the staircase running up alongside of the mutual gable. The proprietor of a flat or storey in that tenement struck out a new door through the wall, dividing his house from the staircase, to which the proprietor of the corresponding flat of the contiguous tenement objected. It was held that the former was entitled to make the door, in respect that the wall was not common property nor part of the common stair, and that the party objecting had not shown any material interest encroached on by the operation.

This case appears to be the counterpart of the cases of Anderson *v.* Dalrymple *(supra)* and Reid *v.* Nicol *(supra)*, certain operations being prohibited in those cases because the objector had a right of

common property in the passage, whereas in Ritchie's case similar operations were permitted because the objector had only a common interest.

The case of Taylor *v.* Dunlop, 1st November, 1872, 11 Macp. 25, referred to a property at the north-east corner of Wellington and Bath Streets, Glasgow. The property belonged to the late Nathaniel Stevenson, who sold to Taylor the upper flat, together with access thereto by a street door from Wellington Street, and the cellars on the sunk floor, inserting in the disposition an obligation on the purchaser to maintain the roof, and on the seller to maintain the street pavement. The defender subsequently acquired the street flat. Taylor proposed to make certain alterations on the property, which were objected to by Dunlop. The nature of the operation may be gathered from the finding of the Court, which was that Taylor, as proprietor of the upper floor, had right to the space between the ceiling of his flat and the roof of the house, and was entitled to make rooms in it with the requisite stair and skylight windows; but that he had no right to carry a flue from the cellar to the roof through the staircase, the latter being intended only for access, and not being Taylor's exclusive property. The Lord President, however, dissented from the finding *quoad* the roof, which, together with the space between it and the ceiling of Taylor's flat, he held on the titles to be not Taylor's property but Dunlop's.

One other case only I shall refer to under this heading. Graham *v.* Greig, 6th December, 1838, 1 D. 171, was one in which the proprietor of the shop flat was by his titles, and by the titles of the upper heritors, excluded from any right to the common stair and staircase, the joint property of which was expressly vested in the proprietors of the upper flats. The latter were found entitled to prevent the proprietor of the shop flat from putting a show-window in or otherwise interfering with the outer wall of the staircase fronting the street.

Having dealt with the mutual gable, partitions, floor-ceilings, and common passages and stairs, we exhaust the remainder of the tenement if we dispose of (1) the walls, that is to say, other than mutual gables and partitions, (2) the roof, and (3) the solum, including the ground actually covered by the tenement, the area in front, the back-green, and the *pro indiviso* pleasure-ground.

The rule as to the ownership of these is generally stated as follows:—"Walls enclosing each flat are the sole property of the

owner of the flat. The roof is the sole property of the owner of the uppermost flat, and the solum (including *pro indiviso* pleasure-ground) is the sole property of the owner of the ground flat; these several rights of sole ownership being qualified by the common interest of the other proprietors."

The rule as thus stated may be accepted as correct so far as regards the walls, the front area, and the back-green; it may, however, admit of question so far as regards the roof and the solum actually covered by the tenement. These it is thought might be argued to be common property in the same sense as mutual gables.

The owners of the lower flats of the tenement are under a servitude of support *(oneris ferendi)* to the owners of the upper flats. Whence arises this obligation? One of the sources of it is perhaps not far removed from the obligation which, as we have already seen, the proprietor of each flat is under to maintain and preserve the mutual floor-ceilings of the flat, and to avoid doing aught to their prejudice. This obligation we have seen enforced in Gray *v.* Greig, 18th June, 1825 *(supra)*. I think, however, the source of the *servitus oneris ferendi* is probably to be found in the fact that each flat has been purchased by, and conveyed to, the owner as the flat of a tenement. It is so described in his title, and as such he is bound to maintain it. The *unum quid* is not the flat but the tenement. The tenement is composed of flats along with a foundation and a roof, which are accessories of, and necessary to, all the flats in equal degree, the roof being the roof of the lowest flat no less than of the uppermost, and the foundation being the foundation of the uppermost flat no less than of the lowest. The foundation and roof, therefore, are truly part and pertinent of the several flats quite as much as is the common gable or the common passage and stair which, as we have already seen, are held to be the common property of the flats which they serve. I incline therefore to the view that, in the absence of special provisions in the title, the roof and the solum, so far as actually covered by the tenement, are the common property of the owners of the several flats; the exigencies of the situation, however, conferring on the proprietors of the ground floor and of the uppermost floor the immediate control and enjoyment of the solum and of the roof respectively, in so far as consistent with the safe and comfortable enjoyment of foundation and roof for primary purposes by the other proprietors interested. I am aware that from some of the

dicta in Taylor *v.* Dunlop *(supra)* one would infer that the roof belonged in sole property to the owner of the upper flat; but the dissent of the Lord President from the finding *quoad* roof in that case detracts to a considerable extent from the weight to be attached to these *dicta*, and I do not think that the practical result in that case was out of accord with the principles already enunciated. It may be true that the owner of the ground flat is very nearly sole proprietor of the solum, and that the owner of the uppermost flat is very nearly sole proprietor of the roof, but it has been a common error to state such propositions too absolutely, and to overlook the principle very tersely laid down by Lord Robertson in Urquhart *v.* Melville, 22nd December, 1853, 16 D. 307, that the "owner of the ground floor is not, in the strict sense of the word, proprietor of the solum to the absolute exclusion of the party above. The upper proprietor is proprietor down to the ground, so far as is necessary for his purposes, just as the under proprietor is proprietor up to the skies, so far as necessary for his purposes."

A few cases in conclusion will serve to illustrate some of the rules I have just been referring to. A leading case is Stewart *v.* Blackwood, 3rd February, 1829, 7 Sh. 362. This case negatives the idea that the solum on which the tenement is built is the sole property of the proprietor of the ground flat. In 1823 an old tenement in Candleriggs was taken down as ruinous by order of the Dean of Guild. It had been owned in flats, and the proprietors being unable to agree about its re-erection, Stewart raised an action of declarator to have it found that the solum of that part of the ground floor which had belonged to him was his exclusive property, subject only to a burden *oneris ferendi* in favour of the defender for her right in the upper storeys, and that he was consequently entitled, in the erection of a new building, to make a sunk storey in that part of the area not occupied by the common passage, so as to give him both such sunk storey and the street floor in the new house. This claim was disallowed by the Court, and it was expressly laid down by the Lord Justice-Clerk that all the proprietors of a house have a joint right to the solum.

In Johnston *v.* White, 18th May, 1877, 4 Ret. 721, and Barclay *v.* M'Ewan, 21st May, 1880, 7 Ret., 792, the area between the tenement and the street was held to be the property of the owner of the street flat to the effect of entitling him to cover it over, by carrying out his shop front to the line of the street.

Arrol *v.* Inches, 27th January, 1887, 14 Ret., referred to a property in Princes Street, Edinburgh, the Balmoral Hotel, which had been subjected to the operation referred to in the two last cases, namely, the covering over of the front area by the proprietor of the lower flats, projecting the street floor forward to the line of the street. The proprietor of the upper storeys then claimed the right to advance his front wall and rest it upon the projection so made by the proprietor of the lower floors. By his title, however, he was expressly excluded from any right whatever in the lower floors, area, &c., and on this express ground his proposed alterations were disallowed by the Court—the under proprietor being held on the titles to be proprietor of the area *a centro usque ad cœlum*, subject only to the law of tenement. But for the express terms of the title the area would have belonged to the lower proprietor *a centro* but not *ad cœlum;* and the upper proprietor, Arrol, would have been entitled to carry out the proposed alteration. Urquhart *v.* Melville, 22nd December, 1853, 16 D. 307.

Boswell *v.* Magistrates of Edinburgh, 19th July, 1881, 8 Ret., 986, was a case of the proprietor of the street flat building on the back green. Under his titles he was proprietor of the green as as well as of the front area. The proposed buildings were distant 20 feet 6 inches from the back wall of the front tenement. At the ridge of the roof they were 19 feet 9 inches, and at the wall head 8 feet 9 inches higher than the top of the street flat; and they were joined to the front property by a saloon. After a remit to Mr. Burnet, architect, the proposed buildings were authorised, subject to certain restrictions, amongst which were (1) that the roof of the saloon with its skylight and cupolas should be no higher than the lowest floor of the upper flats; (2) that the height of the back building should be reduced to 18 feet higher than the saloon; (3) that in the back buildings there should be no windows in the wall facing the back wall of the front property; (4) that the same wall should be entirely faced with white enamelled bricks; and (5) that, for amenity and security from fire, the roof of the saloon should be constructed of concrete and laid with light-coloured tiles.

The Merchant Company of Edinburgh *v.* Cormack and others (George Square Gardens Case), 14th December, 1883, 11 Ret., 57. By the titles of George Square, Edinburgh, each of the feuars had conveyed to him "a right and interest in the centrical area in the middle of the square," jointly and in common with "the

other proprietors of other houses, . . . the proprietors always enclosing, smoothing, laying, and keeping the same in good order, and in an ornate manner; declaring that the said Walter Scott and his foresaids are not to have right without consent of the proprietors of the neighbouring houses to raise the lum heads of the houses hereby feued higher than they presently are, unless the lum heads of such neighbouring houses shall be raised. And also declaring that the said Walter Scott and his foresaids, possessors of the said dwelling-house, &c., shall be perpetually restrained from dealing in, or the occupation of, any trade or merchandise, whether foreign or inland, in wholesale or retail of goods and vivors of any sort or denomination, and from baking and brewing for sale, and from the occupation of any kind of handicraft." The Court held the right of the feuars in "the centrical area" to be one of common interest and not of common property, and that therefore a regulation which had been made and acted on for more than forty years by the proprietors confining the privilege of the garden to occupiers and their families, and excluding children attending school within the square, was valid and binding on all concerned, although it did not appear in the titles.

Ferguson *v.* Marjoribanks, 12th November, 1816, F. C., was a case of the street proprietor proposing to widen his shop door and windows, slap out a door in the back wall, and lower the shop floor. The tenement was a century old, and six storeys in height, but three architects, to whom the question was remitted, reported that the alterations could be safely performed. The Court refused the powers on the ground that the common interest of the upper proprietors entitled them to object to any operations which might occasion even an apprehension of danger.

In Johnston *v.* White *(supra)*, the judges were of opinion that any operation on the walls might be objected to, provided it could be shown to imperil the safety or even the comfort, amenity, or value of the other portions of the tenement.

Subject to these restrictions the Court will allow each proprietor to operate at will on his own walls, the burden being on him to show that the operations can be carried out without apparent risk or any reasonable apprehension of danger. The authorities, for allowing such alterations, are too numerous to call for special mention. The principle is admitted even in the cases where particular operations have been disallowed.

The last point to which I shall refer, and that only in a word, is the case where a tenement belonging to several persons has been burned or has otherwise become ruinous, and some of the proprietors will not consent to rebuild it. In such a case any one of the proprietors may apply to the Dean of Guild Court (if in a burgh), to have the rest decerned to give their concurrence to a plan and elevation being made out, and to build their respective portions within a limited time, or on their failure for a warrant to the petitioner to do the work at their expense. This expense becomes a real burden on the property, and the petitioner may have warrant to let or possess the subjects until fully indemnified. The authority given for this purpose by the Dean of Guild is called "the jedge and warrant."

In concluding these notes I may be permitted to remark that they have not been designed so much to elucidate—still less to exhaust—the law of the subject, as primarily, to answer the communication from the Royal Institute, and at the same time to meet a frequently expressed desire on the part of many of your members for a general idea of the law relating to a subject in which they are specially interested, and of which their practical knowledge not unfrequently makes them, when a new point arises, the skilled advisers to whom judges must naturally look for guidance. If they serve these purposes with any acceptance, I shall feel to some extent excused for having trespassed at so great length upon your time and patience.

XVI.—*On Liquid Diffusion.* By J. J. Coleman, F.I.C., F.C.S., F.R.S.E.

[Read before the Society, 16th March, 1887.]

[Note.—*A Description of the Apparatus and the principal results detailed in this paper were communicated to the Society, 16th April, 1886, but at the request of the Author were not read to the Society until 16th March, 1887.*]

Our knowledge upon this subject is chiefly derived from Graham's classical researches. His first paper was communicated to the Royal Society in 1849, and further papers appeared in 1850 and 1851.

About the year 1855, Fick*, commenting upon these investigations, remarked that it was a matter of regret that in such an exceedingly valuable and extensive investigation the development of a fundamental law for diffusion in a single element of space was neglected, which (he added) it was quite natural to suppose would be identical with the law according to which diffusion of heat takes place in a conducting body, and upon which Fourier founded his theory of heat, and Ohm his theory of diffusion of electricity in conductors. Fick endeavoured to supply this omission so far as common salt is concerned, and Voit calculated the coefficient of diffusion of sugar. Professor Mach, of Prague, has also worked with these substances. Other experimenters have calculated the coefficients of diffusion of salts, or, rather, of a limited number of them, with not very concordant results, as may be seen by consulting the tables of Schumeister attached to the article "Heat," by Sir William Thomson, in the ninth edition of the *Encyclopædia Britannica*, and comparing them with the results of Beilstein, who employed Jolly's method described in "Watts's Dictionary of Chemistry," vol. iii., p. 710. Graham, however, in his latest paper upon the subject, communicated to the Royal Society in 1861, described a method of experiment which, to use his own words, affords a means of obtaining the absolute rate or velocity of diffusion.

* Phil. Mag. [4] x. 1855.

This he called "Jar diffusion," the saline solution being delivered by a pipette to the *bottom* of a column of pure water 127 mm. high, standing in a cylindrical jar 87 mm. diameter, and the amount diffused being ascertained by drawing off the liquid from the top in equal fractions by a very fine syphon, the orifice of the short leg of which was kept close under the surface of the liquid being drawn off.

Graham applied this method to a variety of organic compounds, but only to hydrochloric acid, sulphate of magnesia, and sulphates and chlorides of potassium and sodium amongst inorganic substances.

He did not attempt the calculation of the coefficients of diffusibility in absolute measurements, but remarked that the method is extremely simple, and gives results of more precision than could have been possibly anticipated.

I have recently made a considerable number of experiments with this method; but in place of using jars of 87 mm. in diameter I have employed glass cylinders of 36 mm. diameter, such as are used for "Nesslerizing," and which are very uniform in bore. The annexed Table shows the actual amount of salt found in each section of the liquid after diffusion, expressed in millimetres; the quantity of salt in the upper section being also calculated in percentages of that particular section which at the commencement of the diffusion was the point of junction of the saline solution and the pure water.

The concentrated saline solution was introduced below the pure water by a method slightly different from that of Graham; namely, a fine-bore syphon with contracted orfices was first filled with water, the finger being placed so as to cover the short end; the long end was thrust to the bottom of the water in the diffusion-jar, and the short end was uncovered in a vessel containing the saline solution at a higher level, and the syphoning continued until the height of the liquid admitted under the water in the diffusion-jar amounted to 50 mm.

Many of the results agree with those of Graham, while others are additions thereto, such as the diffusions of mercurous nitrate, mercuric chloride, lithium sulphate, cadmium sulphate, silver sulphate, manganese sulphate, nickel sulphate, and lead nitrate.

Moreover, they are twenty-five diffusions conducted for equal lengths of time, and under similar circumstances as to temperature and methods of experimenting.

Although from many points of view, and especially that of the

Distribution of Salts in Solution Mixtures

Distribution (in % of the total amount) of salts in solution mixtures of different heights

Height in millimetres	$AgNO_3$		KNO_3		$Ba(NO_3)_2$		$Pb(NO_3)_2$		$Hg_2(NO_3)_2$		$Sr(NO_3)_2$		$Mn(NO_3)_2$		$Al(NO_3)_3$		$Cu(NO_3)_2$		$Ni(NO_3)_2$		$Co(NO_3)_2$		$Cd(NO_3)_2$		$Zn(NO_3)_2$		$Fe(NO_3)_3$		Total amount in milligrammes	
	a.	b.	a.	b.	a.	b.	a.	b.	a.	b.	a.	b.	a.	b.	a.	b.	a.	b.	a.	b.	a.	b.	a.	b.	a.	b.	a.	b.
0–10	3810	315	4	4	1024	15	241	241	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111
10–20	4836	410	14	14	1411	21	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111
20–30	6000	64	211	211	3844	336	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111
30–40	7436	710	1111	111	4446	40	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111
40–50	8052	861	1111	111	7710	710	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111
50–60	8113	1470	1111	111	11200	1111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111	1111	111
Percentage	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111

Note. Column (a) gives the weight in milligrammes of salt in each mention appliament off from the top.
Column (b) gives the approximate percentage of weight, assuming the bottom layer to contain 100 of salt.

chemist, most valuable and important deductions can be made from this class of experiments, some of which will be referred to in a later part of this paper, it must be admitted that, from the physicist's point of view, all these experiments are vitiated from the fact that the diffusions should commence with the solid salt or the anhydrous acid or alkali, and end in an atmosphere of pure water. With Graham's earlier experiments a saline or acid solution, the strength of which was gradually diminishing, was diffused into a *weaker* saline or acid solution which was constantly increasing; and even with his latest method of "Jar diffusion" it is practically impossible to work with syphons in long columns of water such as are necessary to get a pure water atmosphere above the salt being diffused. I have therefore turned my attention to improved methods of working, and have devised apparatus, illustrated by Fig. 1, Plate II. This apparatus allows of a very concentrated solution of the substance under examination being admitted at any desired rate of speed underneath a column of pure water of any desired length, and, further, of the liquids being drawn off in regulated quantities at the end of the time of diffusion. No doubt, with solid crystalline salts, theory indicates that diffusion should commence from the salt; but practice determines the fact that, with solid salts, air-bubbles are a difficulty; and, moreover, there are a very large number of salts that are not crystalline at all, and some that do not exist, or are difficult to procure, in the solid state.

Returning to the description of Fig. 1, B B represents a Mohr's burette, 500 mm. long and 15 mm. diameter, provided with a glass stopcock.

The stopcock being closed, this burette is nearly filled with pure water, and is then connected by india-rubber tubing with an apparatus by means of which the air above the water can be slightly rarefied, such as an air-pump or an aspirator, or, by what I find most convenient, an open glass tube, C C, standing in a jar of water. On opening the stopcock of the burette, about half its water escapes, say, to the level (a), rarefying the air above, upon which a column of water rushes up the tube, C C, say, to x. The stopcock being now closed, the tube, C C, is raised and clipped in such a position that the column of water in the tube, C C, is much longer than the water-column in the burette, by which means the air above the water in the burette is sufficiently rarefied to admit of the concentrated saline or other solution being sucked up underneath the water by cautiously opening the stopcock. A

column, say, 100 mm. deep, can be drawn into the burette under a depth of water of 200 mm., which latter can be further added to by filling up the burette cautiously by a long-legged pipette discharged on a cork float. This, however, is seldom necessary except with very diffusive substances, such as hydrochloric acid, which barely reach a height of 200 mm. in 21 days. To prevent leakages, an indiarubber cap is slipped over the point *p* of the burette. At the end of the diffusion-time the liquid is very slowly run off until the level where the water originally joined the saline solution is reached, after which equally-measured sections are carefully removed and reserved for further examination, each section being, say, 25 mm. deep. The results are conveniently calculated in percentages upon the salt or other substance contained in the bottommost layer, where diffusion commenced. It was thought at first that some errors might arise from adherence of the saline solutions to the inside of the burette, down which the upper layers had to pass before estimation. This proved, however, not to be the case to any serious or appreciable extent. Most diffusions are carried on until, at any rate, 1 per cent. of the salt rises 50 mm.; and it was found that sulphuric acid of 1·2 specific gravity, admitted in the burette under water coloured blue with litmus and withdrawn carefully, had so little effect on the water 25 mm. above that it came out of the stopcock barely reddened, and the water lying 50 mm. above the acid came out quite blue. Corroborative experiments were made with saturated cupric sulphate and ammonia as an indicator.

Hydrochloric acid being the most diffusive substance examined by Graham, comparative experiments were made with this compound at temperatures of 12°·5 Centigrade, which show that the rise of the column of hydrochloric acid in pure water is as the square root of the times of diffusion, the periods chosen for diffusion being 7 days, 14 days, 21 days, 28 days, and 35 days. That this is the correct law of diffusion, with a constantly ascending column (as distinguished from Fick's columns "in dynamic equilibrium"), is proved in a most interesting way by a method which I have devised, in which a solution of caustic potash is diffused into water coloured with methyl orange, reddened by an acid. As the top of the column ascends, the red colour of the methyl compound is changed to orange, the line of demarcation being preserved for fully a month, and, in a quiet place and even temperature, with *sing*ular precision.

Fig. 2 shows in the form of curves the results of some comparative experiments made for a period of twenty days at a temperature of 12°·5 C., with the following substances:—

1. Sulphuric acid containing 20 per cent. anhydride.
2. Hydrochloric acid ,, 20 ,, ,,
3. Nitric acid ,, 20 ,, ,,
4. Potassic hydrate ,, 20 ,, ,,
5. Sodic hydrate ,, 20 ,, ,,
6. Ammonia solution of ·880 specific gravity.
7. Magnesic sulphate . saturated.
8. Sodic chloride . . . ditto.

The ammonia solution was floated on the water, the rest admitted under the water, and, with the exception of the magnesic sulphate, the sections of liquid run off were estimated by ordinary volumetric alkalimeter processes.

A summary of the results may be conveniently added:—

Comparative diffusion during twenty days; temperature 12°·5 Cent.

One per cent. of the		hydrochloric acid	rose	250	mm.
,,	,,	nitric acid	,,	225	,,
,,	,,	potassic hydrate	,,	225	,,
,,	,,	ammonia	,,	200	,,
,,	,,	sulphuric acid	,,	175	,,
,,	,,	sodic hydrate	,,	187	,,
,,	,,	sodic chloride	,,	162	,,
,,	,,	magnesic sulphate	,,	87	,,

These results are put forward merely as preliminary experiments with a method which is rapid in execution and susceptible of great accuracy, and which it is hoped will afford or lead to the means of calculating the correct coefficient of diffusion of a large number of substances, Sir William Thomson having kindly promised his assistance in any mathematical calculations necessary.

From the chemist's point of view, several interesting considerations arise from a review of experiments already made, particularly when taken in connection with Newlands' and Mendelejeff's periodic law, which was not put forward until some time after the date of Graham's last paper.

The periodic law classifies the elements into vertical groups of the type R_2O, RO, &c., and into series usually known as horizontal

series. Most of our recent text-books quote the 3rd series as typical; thus:—

	Na.	Mg.	Al.	Si.	P.	S.	Cl.
Atomic weight, . .	23	24	27·3	28	31	32	35·5
Atomic volume, . .	24	14	10	11	14·5	16	27

It will be observed here that, while there is a comparatively small difference between the atomic weights commencing and ending the horizontal series, the atomic volume commences very high at the extreme left, gradually diminishes to less than one half in the middle, and ends very high again at the extreme right of the series. Diffusibility of the compounds of these elements varies in the same way; thus:—

	Na.	Mg.	Al.	Si.	P.	S.	Cl.
	Na_2SO_4.	$MgSO_4$.	$Al_2(SO_4)_3$.	Si_2O_4.	P_2O_5.	S_2O_6.	Cl_2O_7.
Molec. vol. .	55	44	?	45	55	82	?
Diffusibility .	15	4	2·8	?	9·79	18·48	25
	Coleman.			Graham.			Coleman.

The diffusion of chloric acid against sulphuric acid I had to make specially*; the other figures are from the tables and data before given, and the atomic volumes are quoted from Ira Remsen's recent book, the "Principles of Theoretical Chemistry."

Here, then, is evidence that, given a number of elements, the atomic weights of which do not differ widely, the diffusibility will vary in some sort of proportion to the atomic or molecular volume, which latter, indeed, may be to some extent regulated by the energy of the molecules.

Mendelejeff's fourth horizontal series commences with K and Ca, the molecular volumes and diffusibilities of the chlorides being thus:—

	K_2Cl_2.	$CaCl_2$.
Molecular volume, . .	74	44
Diffusibility, ...	41	27

Here again diffusibility corresponds with the larger molecular volume.

---

* By new method of diffusion:—

58 per cent. sulphuric acid rose 25 mm. in 7 days.
29 ,, ,, ,, 50 ,, ,,
12 ,, ,, ,, 75 ,, ,,
70 per cent. chloric acid rose 25 ,, ,,
40 ,, ,, ,, 50 ,, ,,
18 ,, ,, ,, 75 ,, ,,

Temperature 12° Cent.

The fifth series commences with copper and zinc, the molecular volume of the sulphates being exactly equal and the diffusibility nearly equal.

The sixth series commences with rubidium and strontium, the metal rubidium possessing, with the exception of cæsium, the largest atomic volume of any metal yet discovered.

Graham has already shown that chloride of strontium is much less diffusible than chloride of potassium. If, therefore, chloride of rubidium be as diffusible as chloride of potassium, then the diffusibility of chloride of rubidium will be greater than that of chloride of strontium. This has been proved to be the case by the following diffusions which I have recently made. Chloride of rubidium, chloride of potassium, and chloride of sodium were diffused for 10 days at 12° C. in the apparatus represented in Fig. I.:—

Height diffused in millimeters.	Rubidium chloride, per cent.	Potassic chloride, per cent.	Sodic chloride, per cent.
22	68	64	60
44	39	39	31
66	19	19	10
88	7	7	3
110	3·5	3·5	

It will be seen that rubidium chloride is quite as diffusive as potassic chloride, a salt which has hitherto been the most diffusive salt examined. This I anticipated from the large atomic volume of the metal, which is very much greater than even that of potassium; but, on the other hand, its atomic weight is greater.

If a large molecular volume indicates a tendency to rapidity of diffusion, it may be suspected that a large atomic or molecular weight has a tendency to retard it; this, however, is not so easy to prove, from the extreme difficulty of getting groups of soluble compounds, the molecular volumes of which are identical, but the molecular weights of which differ. Moreover, it appears necessary to look for such groups in the family groups of Mendelejeff's vertical series, or the isomorphous groups of the older chemists. The sulphates of zinc and magnesia are strictly isomorphous, and possess an identical molecular volume, namely, 44 when anhydrous, their molecular weights being as 120 to 161.

Graham not only in this case, but in several other cases of isomorphous bodies, strove hard to prove that the rate of diffusion was identical, returning again and again to the subject, on the last

occasion making seventy-two experiments with magnesic and zincic sulphates, which he sums up by stating that the approach to equality becomes close in the 4 per cent. and larger portions of salt, but differed as much as 8·75 per cent. in favour of the sulphate of magnesia in the 1 per cent. solutions.

I have recently diffused these substances for the long period of 50 days, and at a temperature of 15° C., in the apparatus described in an earlier part of this paper as an improvement upon Graham's. The results are that—

9 per cent. of the magnesic sulphate rose 100 mm.
7 „ „ zincic „ „ 100 „

It therefore appears that these substances are not equi-diffusive, and that the one possessing the least molecular weight is the most diffusive. These experiments are very decisive also on the matter of solubility not influencing diffusibility, since the sulphate of zinc is well known to be much more soluble in water than the sulphate of magnesia.

Two substances from Mendelejeff's 6th group, namely, chromic acid and tungstic acid, were selected for diffusion, the molecular volumes of which are identical, and the molecular weights of which are as 100·5 to 232. They were diffused as normal salts of soda for thirty days, at a temperature of 12°·5 C., with this result (in which it will be again observed that the one possessing the least atomic weight is most diffusive):—

25 per cent. of chromate of soda rose 75 mm.
17 „ tungstate „ 75 „

Molybdate of soda was diffused also at the same time, but as the atomic volume of molybdic acid is not identical with, but larger than, that of either of the other two, there was a greater diffusibility, namely:—28 per cent. molybdate of soda rose 75 mm.

In the case of Mendelejeff's 7th group we have chlorides, bromides, and iodides of the following molecular weights and volumes:—

	Mol. wt.	Mol. vol.
Sodic chloride, ...	58·5	26·0
„ bromide, ...	103·0	33·0
„ iodide, ...	150·0	43·5
Potassic chloride, . . .	74·6	37·0
„ bromide, . . .	119·1	44·0
„ iodide, . . .	166·1	54·0

In all these cases it will be noticed that there is an increase of molecular volume simultaneously with an increase of molecular weight, so that it is possible that retardation of diffusibility, owing to an increased molecular weight, may be counterbalanced by an increased energy, indicated by the larger molecular volume; and it may account for the singular fact discovered by Graham that these substances are practically equally diffusive, though further experiments may show some little variations. Similar remarks may be made in regard to the chlorides and nitrates of calcium, strontium, and barium, which Graham also showed to be practically equally diffusive:—

	Mol. wt.	Mol. vol.
Calcic chloride, ...	111	44
Baric chloride, ...	208	54
Calcic oxide, ...	56	18
Strontic oxide, ...	103·6	22
Baric oxide, ...	153·0	28

In regard to Mendelejeff's 8th group, I have diffused ferrous sulphate, cobaltous sulphate, nickelous sulphate, and cupric sulphate, the molecular weights and volumes of which are as follow:—

	Mol. wt.	Mol. vol.
Ferrous sulphate, ...	152	48
Cobaltous sulphate, . . .	155	44
Nickelous sulphate, . . .	155	?
Cupric sulphate, ...	159·4	44

The diffusions were carried on fifty days at 10° C.

11	per cent.	of the	iron	rose 100	mm.
10	,,	,,	cobalt	,,	,,
10	,,	,,	nickel	,,	,,
10	,,	,,	copper	,,	,,

The diffusion rate of these substances, which closely approximates those of Mendelejeff's 2nd group, the Dyads, also corroborates the other experience as to the influence of the molecular weights and volumes.

The difference in diffusibility, however, between the first or Monad group of Mendelejeff, and his second, or Dyad group, is

very striking and can be approximately represented by the following figures —

Group I. Formula R_2O [Monads].

	Sulphates.	Nitrates.	Chlorides.
Lithium.	11	'	'
Sodium.	17	28	34
Potassium.	24	30	42
Silver	27	35	insol.
Average	27	32	38

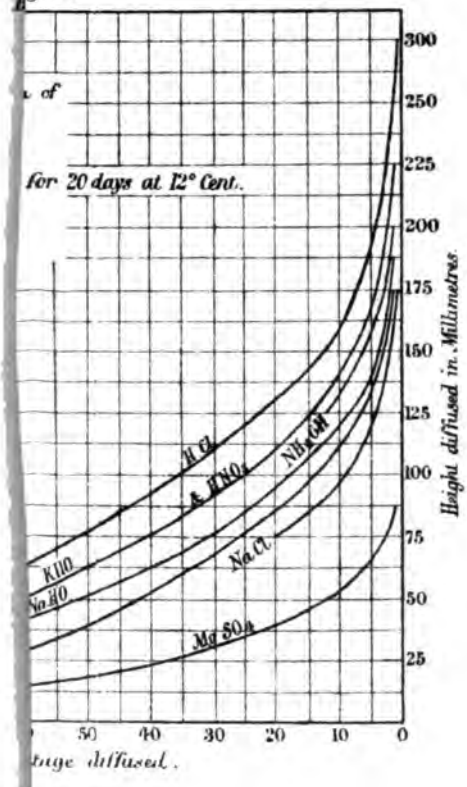
Group II. Formula RO [Dyads].

	Sulphates.	Nitrates.	Chlorides.
Magnesium.	4	21	23
Cadmium.	5	'	14
Zinc.	14	23	23
Mercury.	4	13	10
Calcium.	insol.	23	27
Strontium.	insol.	23	27
Barium.	insol.	23	28
Average	7	21	21

Mendeleeff classes cuprous salts with Monads: and it is singular that very early in his experiments Graham pointed out that cuprous chloride has only half the difficulty of cupric chloride.

I am still prosecuting the investigation, and other interesting relationships may be detected: but the data as to the specific gravity and molecular volumes of compounds of many of the rarer elements are entirely wanting, and even in the case of those of well-known elements are incomplete

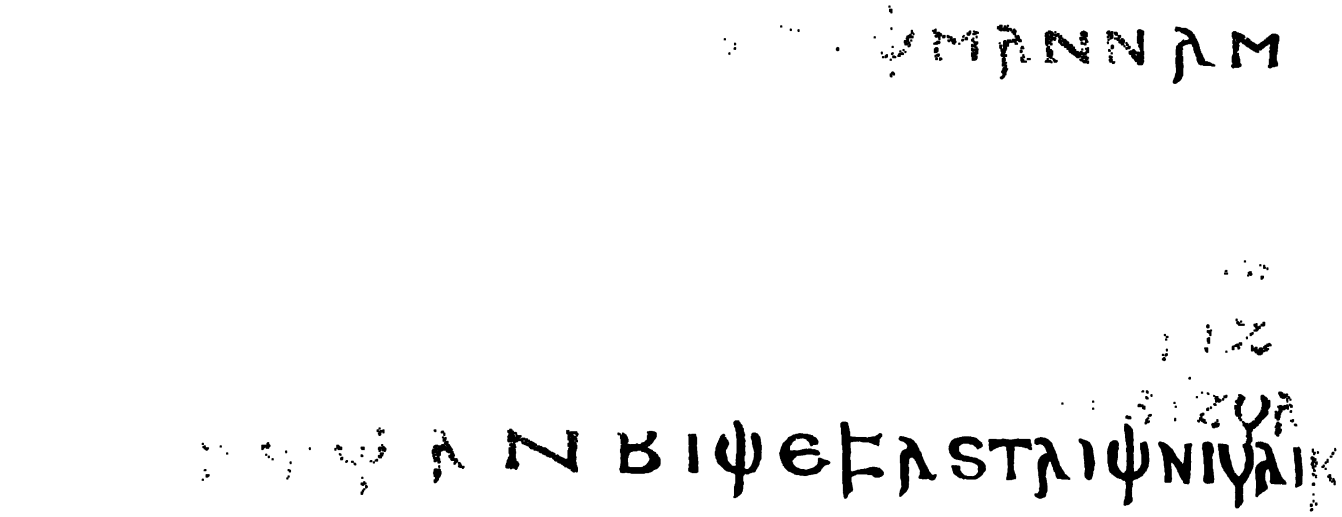
Fig. 2



B

Martin Macdonald & Co.

Facsimile of Gothic Codex Argenteus.



MATT. VI. 13-15.

XVII.—*The Gothic Version of the Gospels by Bishop Ulfilas, and its Value in the Study of Language.* By James Colville, M.A., D.Sc. (Edin.)

[Read before the Society, 4th May, 1887.]

The tourist on the Rhine, looking down from the deck of his steamer as it breasts the tawny stream, will frequently pass in his course a slow procession of barges deeply-laden with coal. If of an inquiring turn of mind, he will learn that these hail from the Ruhr, a tributary that enters the great river near Düsseldorf, the valley through which it flows enjoying a brisk trade in coal-mining and its allied industries. Three centuries ago, in an obscure monastery of this side-valley, in the little town of Werden, an inquisitive German—one Arnold Mercator,—rummaging among the dusty tomes of its library, perhaps in search of plunder for his master, the Landgraf of Hesse, discovered a manuscript of rare beauty. As the Lutheran Reformation was then making havoc of monastic stores, the prize was removed for greater security to Prague. It had been written by some careful scribe, in characters of silver on a purple or mulberry-tinted parchment. The letters of a few words at the beginning of each paragraph were in gold. How it had come to Werden no one could tell, but experts are agreed that it must have been made in Italy towards the end of the fifth or the beginning of the sixth century, *i.e.*, during the rule of the Goths under Theodoric the Great. It was, indeed, a version of the Gospels in the language of the Goths. Towards the end of the Thirty Years' War in 1648, Count Königsmark, having captured Prague, took the MS. to Stockholm. Thereafter it had further adventures, having been for a time in Holland, but it was ultimately restored in 1669 to the royal library at Upsal, where it still remains. It contains the Gospels in 339 leaves, of which 177 are preserved, and is known as the Codex Argenteus. While in Holland it was printed for the first time at Dort, 1665, by Francis Junius, well known to literary students as the first to give the

deep recesses of the foot-hills, winding bay and receding creek bring the sea-breeze that fills the social sail and tempts to a larger trade and a wider knowledge. Northwards, on the other hand, stretches an almost sub-arctic sea, broken into two irregular halves by peninsulas, its shallow waters washing dreary sandy shores, on every side a vast plain covered for ages with a dense forest through which mighty rivers pour their sluggish waters into storm-tossed seas, and ever overhead a changeful sky, now vexed with the drifting cloud-rack, now hid behind a pall of murky fog. Southern mountain-land, northern plain—these have ever been the respective homes of the Roman and the Teuton. The Goths swooped down upon the eastern peninsula, the Vandals upon the western, where the name Andalusia still marks their footsteps, while the fierce Ber-serkr sailed his dragon prow through Ægean seas, but in time they lost their identity amid the orange groves and beneath the blue skies of the south. Equally marked is the contrast between the pleasures, the business, and the thoughts of the two races. South of the Alps the unit of national life is the *polis* or the *urbs*—a busy city-life, quick-witted, eloquent, artistic, thronging *agora* and *forum* under the shadow of each rocky acropolis. In the huge, formless, northern plain, on the other hand, man is lost in the world of mingled wood and water. His clearing in the forest is his homestead, the centre of social life. Round it he plants his prickly hedge and calls the whole his *tun* (Ger. zaun, a hedge), the most general Teutonic place-name. In Gothic *tains* is a branch of the thorn-bush, *tain-jo* the woven basket that received the fragments after the feeding of the five thousand. Here the family and not the bazaar is the unit.

In the ancient world the Roman and the Teuton met again and again in conflict. The Empire held its own for a time when, across the Rhine and the Danube, securely flaunted the eagles of the legions. But decay set in and the Danube became the scene of danger. By the middle of the third century the Goths overran the whole country between the Baltic and the Black Seas. Round the Carpathians they swarmed, seized Dacia (the modern Wallachia), crossed the Danube, and in 251 they met in battle and slew the Emperor Decius. Then, sweeping over the Balkan Peninsula, they crossed into Asia, ravaging as far as Trebizond and Cappadocia. But in 269 they suffered a check at the hands of the Emperor Claudius, and for ninety years there was peace. Those *north of the* Danube came to be known as East Goths, those on

the south side as West Goths. Ermana-ric, or Herman-ric, made of the former a powerful dominion that had ultimately to succumb to that terrible scourge of Eastern Europe—the Tartar Huns.

Meanwhile, the West Goths were torn by internal dissensions. A patriotic and apparently conservative party under Athana-ric was opposed to the Christian and Arian party under Frithigern, with whom Ulfilas sympathised. The latter, to avoid persecution, led a colony through the Balkan Passes and settled within the Empire in what is now Bulgaria. This peaceful movement was, however, thwarted by cruel treatment that resulted in a rising in which the Emperor Valens was slain at Adrianople in 378. His successor, Theodosius, made terms with the Goths, and many of them joined the legions. In subsequent Gothic history great names appear;—Alaric, the hero of national independence and unity, strong enough to sack Rome itself; Ataulf, the loyal ally and son-in-law of the Emperor Theodoric, who fell in battle with Attila, the Hun, on the Frankish plain of Chalons; and, finally, Theodoric the Great, the protector of the peaceful Roman against the Gaulish Odoacer, and Emperor of the once more united Western Empire. Therefore it is that in the Italy of the fifth century we find the last reliable traces of the Goths—the Codex Argenteus, other fragments of the Ulfilic translation discovered as late as 1817 and preserved at Milan, a Gothic calendar, and a business document, the owner of which lived at Arezzo, near Naples. In Italy, however, the Goth was but a temporary invader; in Gaul and Spain he held his own for long, ultimately succumbing to the Frank and the Moor.

On what is known as the Bucharest ring is a Runic inscription consisting of three genuine Gothic words—Gut annôm hailig—dedicated to the Goths' treasures. Each of these words occurs in the Ulfilic Gospels. From this we learn that the Goths called themselves Gut-os, in the singular Guts; to the classical writers they were the Gothones. There seems to be a real confusion between the sounds of ū and ō. Ulfilas speaks of the Epistle *Du Rumonim* to the Romans, and calls Rome *Ruma*. Shakspere, too, rhymes Rome with *doom* and *groom*, and in "Julius Cæsar" *Cassius* says:—

> "Now is it Rome, and room enough
> When there is in it but one only man."

The Ulfilic form survives to this day in the name Roumania. The

fuller name for the Gothic people is Gut-thiuda. The latter part of this term is the German national name Deutsch for Deut-isch, in Gothic Thiud-isk; it is from a root wid[e]ly diffused in all the Indo-European tongues, to which, of course, Gothic, as a Teutonic speech, belongs. The branches of the Indo-European family fall into three distinct groups:—I. Sanskrit, Old-Persian, Greek, Latin, Keltic, Slavonic; II. Low German (Frisian, Dutch, Norse, Scotch, English); III. High German. Of these the first to appear in Europe must have been the Keltic; the outstanding physical features of our continent—mountains, rivers, valleys—bear Keltic names. The last to appear, and the lowest in the scale of culture, is the Slav. The affinities of these tongues have long been established, and the principles involved are formulated in the well-known Grimm's Law. The most striking illustrations of the law are to be found in such familiar and widely-diffused words as numerals, pronouns, and terms for relationships, common natural phenomena, domestic animals, and the like. The law affects merely the nine mutes, as arranged in three sets, viz.:—Hards, Aspirates, Softs, the initials of which form the mnemonic H. A. S. Any word common to the three groups stated above will change, as far as its mutes are concerned, from group to group in the order of the groups and the order of the sets of mutes. These changes can be shown diagrammatically, thus:—A circular disc, divided into three arms corresponding to the three groups above, is made to revolve from left to right within a circle or outer rim, which latter is divided into three compartments corresponding to the three sets of mutes—H. A. S.

The typical illustrations of the law in the three positions of the disc are these :—

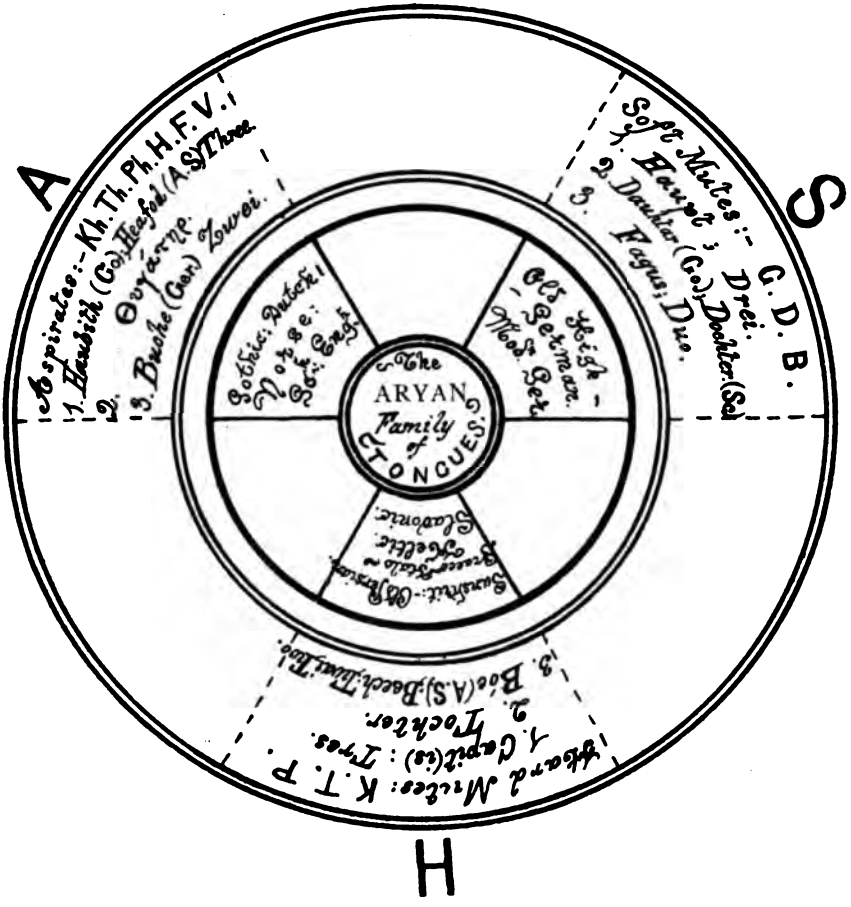
1st Position.—Group I.	Hard.	
Sanskrit, Græco-Latin, Keltic, Slavonic.	K. T. P.	Ca p i t (is) (Latin). T res (,,).
Group II.	Aspirate.	
Low-German.	Kh. Th. Ph. h. f. v.	H au b i th (Gothic). H ca f o d (Anglo-Saxon).
		Th ree (English). Th reis (Gothic).
Group III.	Soft.	
High-German.	G. D. B.	H aup t (German). D rei (,,).

Proceedings of Philosophical Society of Glasgow. 1886-87. Plate IV. Vol. XVIII

GRIMM'S LAW

of

Consonantal Change.



2nd Position.—Group I.	Aspirate.	Θ πάτηρ (Greek).	
,, II.	Soft.	D auhtar (Gothic). D ochter (Scotch).	
,, III.	Hard.	T ochter (German).	
3rd Position.—Group I.	Soft.	Fa g us (Latin). D uo (,,).	
,, II.	Hard.	Bó c (Anglo-Saxon). Beech (English). Bo k a (Gothic). T wai (,,). T wo (English).	
,, III.	Aspirate.	Bu ch e (German). Z wei (,,).	

We should not expect too much of this law, for it applies merely to a few consonants, and even here there are many exceptions. High-German has been, for instance, immensely influenced by Low-German, and has accordingly often changed its original hard lip mute p for b. This latter must itself have been very imperfectly individualised before the great break-up of the common stock. The law, indeed, is very imperfect as regards German, not only in the lip but, also in the guttural series. In the middle or dental position, however, the groups are clearly distinguished. Each tongue has, in these respects, as in others, developed on its own lines, and produced idiosyncrasies due to the most powerful agent in linguistic variation—dialectic growth. Of far more value are the laws regulating the internal development of each language, and all that gives it character and individuality. The consonants are but the hard unyielding bones of a word; the vowels, on the other hand, body forth those subtler influences of tone, accent, and quantity that form the covering of flesh, complexion, and feature, differentiating the individual, the tribe, and the nation. True progress in philology lies in a mastery of phonetics as applied to the vowel-system of a language, and especially of its dialects.

Our own language, that is to say, English and Lowland Scotch—for they are substantially the same—is more nearly related to Gothic than any other Indo-European speech, brought as it was to our shores by the English folk, those Low-German tribes that had spread westwards to the dreary Frisian shores when their brothers, the Goths, roamed towards the banks of the blue Donau, to waste their strength in a life-long struggle with the mighty power of

Rome. The study of these Gothic remains therefore constitutes, not merely a unique field of linguistic research, but is of practical value in helping to a right appreciation of the history of our own tongue.

In all probability Ulfilas reduced his native Gothic to writing for the first time, and for this purpose constructed his alphabet on a basis of Runic, Greek, and Latin characters. As to which of the three formed the primary basis, scholars are not agreed. German writers, whose views are endorsed by Mr. Douse, assign this position to the Runic alphabet, while Prof. Skeat discusses the whole point without the slightest reference to Runes. The question is a difficult, but not very momentous one. Written symbols of every kind are peculiarly liable to change. We all use the same conventional set of cursive characters, and yet in practice these assume endless varieties of form. Further, it is more than likely that both Runic and Greek, *i.e.*, Phœnician characters, diverged from a common source. Runes form an undoubted relic of Teutonic antiquity. Widely diffused over northern and western Europe, they acquired a mystic force from their extensive use in charms and divination. They have not come down to us in connection with literary remains, but merely in incised inscriptions on stones, crosses, weapons, &c. The word rune (Go. runi and A.-S. rûn) means a mystery, not a letter, for which Ulfilas uses *boka*. In O-Eng. and Sc. the verb to *roun* or *round* means to whisper, and its cognate Lat. *rumor* properly means a whisper, while in its Sanskrit form—*bru*—the word means to speak, and is very commonly used. It may here be noted that Runic letters are formed almost entirely of combinations of straight lines, generally in threes. All writing is indeed a variety of printing or graving that has become more and more cursive. Thus s, which has now its familiar serpentine form, shows, as a Rune, three lines *en zigzag*, as in the oldest form of the Gr. sigma. Again, the Runes had names attached to them, showing their pictorial or hieroglyphic origin. Thus the first is *f* = *faihu*, the Go. cattle; Sc. fee, Ger. vieh, just as in Heb. al-eph is the ox. O is *ôthal* an heirloom, inheritance, not extant in Gothic, but in Orkney applied as *udal* to a form of land tenure, and as *udaller* familiar to readers of Scott's "Pirate." The Norsemen in Ireland made it O'Dell. T again is Tius (Tues-day), the Northern Jove, wielder of the thunderbolt, which indeed the character symbolises, for it is *nothing* but the Government broad arrow. Ulfilas significantly

ALPHABET.

Runic.
Gothic.
Greek or Latin.
English Equivalents and Numerical Values.
a, 1.
b, 2.
g, 3.
d, 4.
ê, 5.
{q} kw, 6.
z, 7.
h, 8.
th, 9.
i, 10.
k, 20.
l, 30.
m, 40.
n, 50.
{gg}
Runic.
Gothic.
Greek or Latin.
English Equivalents and

eschews the use of this heathen name. But that his people must have been familiar with Runes and their names, is believed to be proved from a curious Viennese MS. of the ninth century containing the Gothic alphabet, with the recognised Runic names for the letters. Not many of the Runes, however, were adopted by Ulfilas without modification under Greek influence. A is more Runic than Gr.; b, i, r, are common to both systems. The Rune u seems clearly repeated in Gothic, yet Prof. Skeat regards it as a Lat. u inverted. He is equally determined to ignore Runes in the case of o, which symbol reproduces a Rune very fairly, yet some see in it Gr. omega, and Skeat the inversion of a Gr. contraction for ou 8. Some of the symbols are certainly Greek:—g (hard), e, k, l, n, p, w (upsilon), and ch, used merely in such proper names as Christos. Ulfilas does not give ch its Runic nasal force, for which he doubles g as in Greek, *e.g.*, *briggan*, to bring. From the Latin alphabet he borrowed, it is thought, d, h, m, s, t, and f, of which the two first are not at all Runic, but m is equally Runic and Latin, though with a different phonetic value, and s, t, and f can be easily traced to runes. Gothic j (as y in yes) Skeat gets from Lat. g, yet this, too, looks like a modified Rune of similar value. There remain the characteristically Gothic kw, hw, and th. The first Mr. Douse regards as a Rune for qu, used as a number = 90, but Prof. Skeat the Lat. u. Hw cannot be accounted for; but Prof. Skeat considers it Gr. theta, while to explain the thoroughly Teutonic th-symbol he resorts to the far-fetched device of inverting Gr. phi. The Anglo-Saxon thorn-letter closely follows the Runes. Lastly, Ulfilas uses his letters as numbers, hence we know their sequence, which is that of Greek, not Runic, where the alphabet was known as *futhork* from its first six letters, viz., f, u, th, o (for a), r, k.

It is interesting to know the phonetic value Ulfilas probably attached to his symbols. This we ascertain from two sources, a comparison with the general Teutonic vowel and consonantal system, and a study of Ulfilic transliterations of Greek proper names. His vowel system is :—

Short ă as in *manna* = Sc. man.	Long ā, rarely used.
,, ai for ĕ as *airtha* = earth.	,, ê as *gêbun* (gayvoon), they gave.
,, i as *fisks* = fish.	,, ei (ī) as *weis* (weece), we.
,, au for ŏ *daur* = door.	,, ô as *wôk*, I woke.
,, u as *suns* = soon.	,, û as *suts* (soots), sweet.

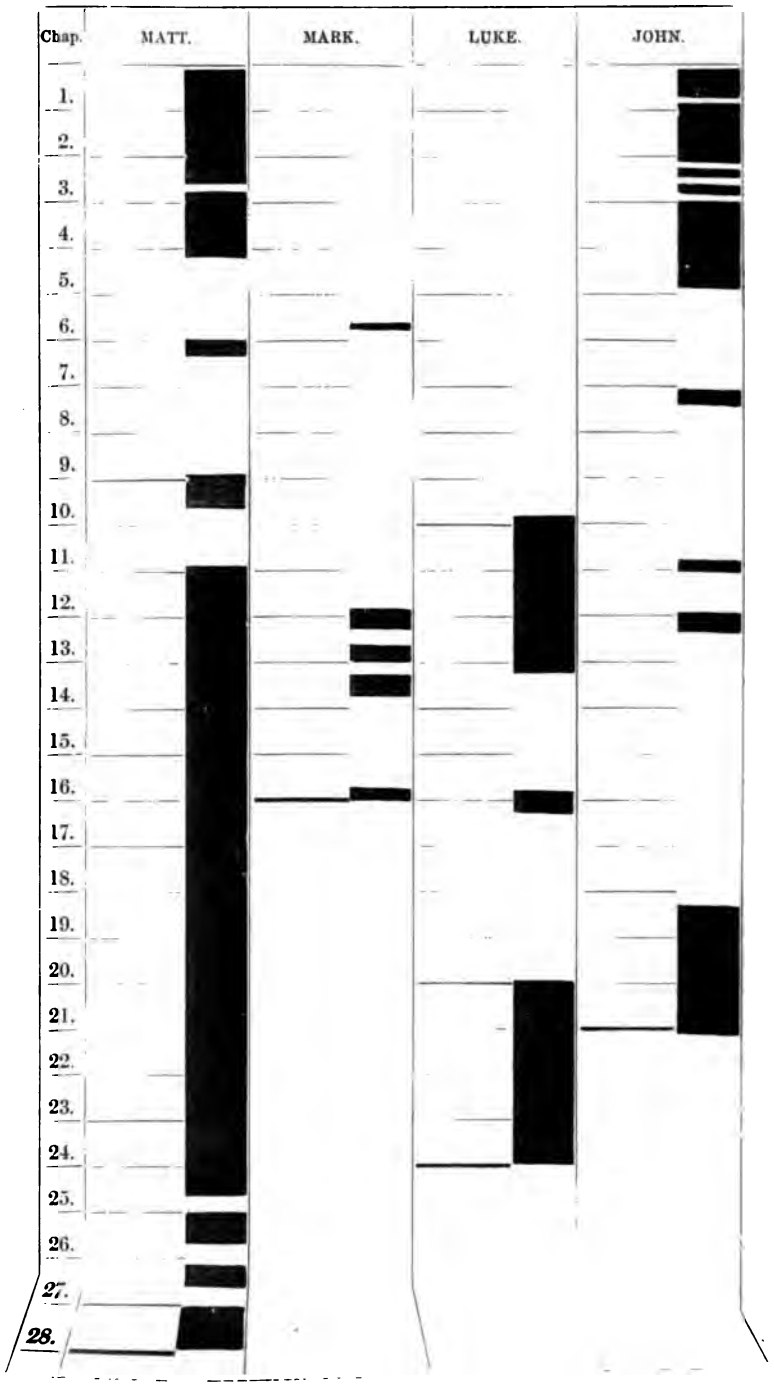
The Greek transliterations for the most part bear out these values,

but it is probable that Ulfilas found his vowel system different from the Greek. It seems strange that, having adopted Gr. eta as a symbol, he should have given it the long sound of upsilon, and chosen to use ai for the short sound, thus—Baiailzaibul = βεελζεβοὺλ, Gaiainna = Γεέννα, Gehenna. Similarly, o is always long, and au represents its short sound, as Apaustaulus, ἀποστολος. These short sounds ai = ĕ and au = ŏ, are almost restricted to those cases in which these vowels are followed by r or h. A somewhat similar disturbing effect of r is still seen in clerk, Derby, and less correctly in servant (sarvent), and sergeant (sargent). The combination ai and au elsewhere have the values of Ger. Kaiser and Haus respectively. Long i is ei = ee in seen, but the transliteration varies, Go. ei representing Gr. ι, ει, and η, *e.g.*, Aileisabeth = Ελίσαβετ, Jaeirus = Ιάειρος, and Atheineis = Αθῆναι. The consonants do not call for much remark; g has always its hard sound, j, which has now its palatal sound under the influence of French, has the sound of y in yes; p seldom appears in Gothic words except in the middle position, and b has the force of f or v between vowels. In course of time the Go. consonants have become greatly altered. Thus Go. s is often Eng. and Ger. r, *e.g.*, raus, a reed = Ger. Rohr, dius, a beast = deer, auso = ear, huzd = hoard, gazd, a goad = yard, haus-jan, to hear. Go. b is f in laub = leaf, giban, to give. H is always in Go. a strong guttural, as hauh = high, Ger. hoch, Sc. heech. But the strongest changes appear, as is natural, in double consonants, for here we encounter a potent factor in phonetic change, human laziness. Initial sk = sh in skoh = shoe, skadwus = shadow, skainan = shine; hr and hl lose h, as hlauts = lot, hlah-jan, laugh, hlaifs = loaf, hlaiw = law, a hill, hraw = raw, hruk-jan = rook, hwairban = warp, hliftus, thief (cattle-lifting). Sc. sometimes preserves this initial sound as in Go. hropjan, to call, Sc. hraep, sometimes heard as thraep, to argue. The difficult sound th is often changed to d, as Go. maurthra = murder, sinthan, to go, wander = send, hlethra = ladder, but Sc. lether, sneithan, to cut, Ger. schneiden, Sc. snod, balths = bold, kiltheis = child. In Sc. th is often heard for Eng. d, *e.g.*, shouther = shoulder, poother = powder, bethel = beadle. Lastly, initial hw, common in Go., is now either wh or simply w. Only in Sc. is the original sound preserved. Our *which* is a good illustration of phonetic change—in Go. hwileiks, in Sc. hwilk, but in Eng. which, or, rather, witch. A countryman, sauntering near the Strand, asked a passer-by, "What street is this?" The answer, "Wych Street,"

made him repeat his query, whereupon the Londoner testily said, "W'y, Wych Street, of course," and walked on, doubtless mentally objurgating Doric dulness.

If we turn now to the Ulfilic remains as we find them, it may be asked, With what degree of completeness do they present the Gospel narrative? The second Gospel is almost complete, the others show numerous and extensive *lacunæ*.* Of not one of the Gospels is the concluding portion preserved. The last words of the narrative, as a whole, form the report of Mary Magdalene, that she had seen her risen Lord on the first day of the week. We miss the marriage supper at Cana, the interviews with Nicodemus and the Samaritan woman, the good Samaritan, the Agony, and the institution of the Lord's Supper. But we have the story of our Lord's birth and early life, the episodes of the Baptist and the Temptation, the great miracles, the best discourses, such as the Lord's Prayer, Sermon on the Mount, and the farewell to the disciples, the most familiar parables, the entry into Jerusalem, the trial, crucifixion, and resurrection. A closer scrutiny of this unique relic ought to proceed on three lines:—(*a*) what are its merits as a translation? (*b*) what does it reveal of the material, social, and intellectual condition of the Goths at the time? (*c*) what are its affinities with Scotch, English, and German?—the modern languages with which it is intimately connected. From the philologist's point of view the first may be passed over. Ulfilas keeps faithfully to the Greek text, and in the spirit of Old-English, and the prevailing practice of modern German, he refrains from adopting a foreign word, but prefers, if possible, to translate it. In this respect we have long enjoyed Free Trade, and freely admitted within our shores an unlimited number of foreign words, not unfrequently ousting good native products in the process. Many terms, however, Ulfilas adopts. The Greek-borrowed words include those connected with the church services, dress, and articles of utility or refinement, such as paska (old Scotch *pash*, Easter), purple-dye, sackcloth, olive-oil, myrrh, linen, mustard. The Latin, on the other hand, refer to war, government, money, and the like, such as *Cæsar* (Kaisar), *pretorium*, *militare*, *regere*, *cumbere* (to sit at meat), *fascia*. Of these native equivalents the following may be taken

* The accompanying diagram shows the gaps in the MS. referred to. The passages awanting are shown in black.


Chap.
MATT.
MARK.
LUKE.
JOHN.
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.
22.
23.
24.
25.
26.
27.
28.

as samples:—bookers = scribes, finger-gold = ring, hunsel-stead = altar, *i.e.*, (Sc. hansel)-place; wine-berry = grape, hundred-lord = centurion, ladder-sticks = tabernacles, harns-stead, *i.e.*, brains-place = Golgotha, the place of a skull.

Of more vital interest is the evidence these remains afford of the condition of life of the Goths. In one respect they have the advantage of preserving in transverse section a petrifaction, as it were, of contemporary speech. On the other hand, the limited range of subjects in the Gospels excludes many departments of social and intellectual activity. We miss the language of war and the chase, of the social pleasures, of folk-lore. But it must be admitted that the Gospel narrative comes very near to our "business and bosoms," so we should expect to find in the language of Ulfilas no lack of homely and intelligible terms. A glossary arranged, as it is, alphabetically, conceals the evidence it bears of social and intellectual status. More instructive would it be to have the words classified under subjects. The main heads might be (1) Man and his personal environment (man generally, parts of the body, relationships, dwellings, dress, feelings); (2) Man's remoter natural surroundings (plant and animal life, the weather, time, &c.); (3) Man's forms of activity (occupations, war, civil life, education, and religion). Under these heads a mass of most interesting words are to be found in Gothic, most of which are still in use among us, the rest are quite familiar to a Scotchman, and in a large degree to a German. All of them have a history in themselves and in the affinities they suggest.

Here follow some specimens of this instructive catalogue:—

I. MAN AND HIS PERSONAL ENVIRONMENT.

Man generally.—*Wair* = Lat. vir, the strong one, the hero, obsolete but seen in O.-Eng. wer-old = world, Sc. wardle, *e.g.*, "Eh, sirs! sic a weary wardle" ("Johnny Gibb o' Gushetneuk"). It is found, but obscurely, in Canterbury = Roman Cant-uarius = bury or town of the men of Kent. In this word *er* represents A.-S. waru = wair, common in old place-names. In Gael. wair is *fear*, as in Mac-Pherson. *Guma* = homo, the earthy one (bride-g(r)oom, yeoman). *Queins* = γυνή, the producer, used for woman generally, our queen, Sc. quean.

Parts of the Body.—*Leik* = body generally, dead or alive, very common in Eng. as in lich-gate, lyke-wake. *Hwairnei* = brains, Sc. harns, Ger. Ge-hirne, renders Golgotha = hwairnei-staths, place

of a skull. *Lof-a* = Sc. loof, cf. die flache Hand, the open palm. "Some standing by struck Jesus with the *lofa* (loof)."—John xviii. 22. In A.-S. it is lôf. Beowulf has g-lôf, our glove, an almost solitary trace of the prefix ge, so common with nouns in Gothic and German. Gothic shows that our *gallop* has also a trace of it in verbs, for it is Go. *ga-hlaupan*, to run, our leap, Sc. lowp, Ger. laufen, Eng. loafer and inter-loper. *Kinnus* = the cheek, our chin. Sc. keeps *k* in kin-cough for chin-cough, Du. kink-hœst. Literally it is the curved, crooked, as in kink, a twist in a rope, Sc. kinch. *Taihs-wa* = dexter, the pointer or right hand. Gothic has a word for *one-handed* = *hamfs*, in the general sense of maimed, "If thy hand offend thee, cut it off; good is it for thee to enter into life one-handed than to enter Gehenna having two hands" = "Jabai marzjai thuk handus theina, afmait tho; goth thus ist *ham-famma* in libain galeithan, than twos handuns habandin galeithan in gaiainnan."—Mark ix. 43. *Haihs* = one-eyed, a curious compound, according to Bopp, of the -ce of ec-ce hic-ce, e-ka (Sanskrit one) along with the common Aryan for the eye, Go. augo, Lat. oc-ulus. The whole is therefore in the Roman name Horatius *Cocles* = the one-eyed. The syll.-ha = ka (Sans.) is in both hamfs and haihs. Hamfs = ha-nifa, Sc. neive, fist.

Relationships.—Our word *father* is not in Go. except in *fadr-eins* = parents or family (Joseph was of the house of the *family* of David). Its stem is in hund-faths = master of a hundred and bruth-faths = lord of the bride. Faths is *fode* = a man, in our old ballads such as Cheild Rowland and Burd (bride) Ellen, *e.g.*, "God rue on thee, poor luckless fode, what hast thou to do here?" The root of these means *the protector*, and is more classical than Teutonic. *Mother* is nowhere in Go. The place of these two terms is taken by the onomatopoetic *atta*, *aithei*. Such words are common, *e.g.*, abba, papa, tata (Vaidic and Greek), and dad, hence Att-ila, the Hun = the little father. The Czar is still to the Slavs the little father. Attâ in Sans. is mother or aunt = Go. aithei. *Widuwo* = widow, the bereaved one, really an adj., as *viduus* ager, a fallow field, in Lat. This is also its force in Go. and Sc. The woman of Sarepta is "quinon widuwon" = a widow woman.

Dwellings. — Gothic has for πόλις, *baurgs*, burgh = a walled place. A smaller collection of houses is either *weihs* = vicus, *haims* = Sc. hame, ham-let, or *thaurp* = thorpe, Ger. Dorf. The town Wick is not *weihs*, but, like *vik*-ing, is from Norse *vik*, a creek, bend, bay, from the root of *weak*. *Gud-hus* is the only use of

our word house in Ulfilas, and means God's-house or temple. The common term is *gards* = yard, a hint that there prevailed among the Goths that primitive type of farm-life in which a settler effects a clearing in the primeval forest and encloses his home (cf. Sc. farm-toon), for this is the radical sense of both *gards* and *toon*. *Hrot* = roof is what is uncovered to admit the paralytic into the house where Jesus was. In the Heliand, a Low-German poem upon the Saviour, of the 9th century, the sufferer is admitted "thurk thes huses hrost" = through the house's roof. Hrot, roof, roost, roast are all the same, originally the rafters on which the fowls perched. "Rule the roast" has nothing to do with roasting, but is like "Cock of the walk." *Ubizwa* = eaves, shows that our own word is not really a plural. *Gibla* = gable, Sc. and Du. gevel is that pinnacle of the Temple to which the Tempter leads Christ. Inside the Gothic house there was the *mes* (mess) or table, while the hearth, ashes, oven, smoke, kettle, pot, stool, bed, all bore names still common in Sc. or Eng.

Dress in general is *wasi* = Lat. vestis. *Paida*, a coat of skins, to this day the dress of Slavonic shepherds, is said to be in pea-jacket, which has come through Dutch. Another hint of a national peculiarity in dress we get. When Mary wiped Our Lord's tear-moistened feet, Ulfilas uses for our phrase, "the hairs of her head," *Skufta haubidis seinis*. *Skuft* is the top-knot, Ger. Schopf. The Greek here simply says Θριξὶν τῆς κεφαλῆς.

II. MAN'S NATURAL SURROUNDINGS.

Natural Phenomena.—To Ulfilas heaven and earth, sun, moon, and stars, sea and land, berg and dale, stone, fen, flood, water, burn, gold, silver, iron, salt, were known by precisely the same names as to ourselves. The sun was known by two names, *sunno*, fem., and *sauil*, Lat. sol. neut. The sea was the *saiwa*, the tossing one, the lake *marei*, the O.-Eng. mere. A country district was a *gawi*, still heard in Rhein-gau and Miln-gavie; a field was *hugs*, a haugh, or *akrs* = acre, Lat. ager. *Ahwos*, torrents of rain, is aqua, the universal Aryan word for water.

Plant Life.—Grass is Go., but not in its restricted sense, rather herb. The mustard seed is the greatest of all the *grasses*, cf. gorse. In our sense *hawi* = hay is used, *e.g.*, "If God so clothe the hay of the field." For fruit generally, especially of the fields, we have *akran* (akrs = field), our *acorn*, now restricted in sense. It has nothing to do with the word oak. Tree generally is bagm = beam,

Ger. baum. Timber is *triu* = tree. The band that came to the garden to seize Christ were armed with trees (staves). This explains the expression "nailed upon the tree," spoken of the Crucifixion. Strange to say, Go. gives no native tree-names. Of grains, three bear the modern names:—Atisk* = Old Sc. aitis, oats, lit. what is eaten, but used for the field of corn (σπόριμον) through which our Lord walked on the Sabbath-day. In the A.-S. Bible we read "Thā Noë ongan him *aetes* tilian" = then Noah began to get him food. *Hwaits* = wheat, sounds quite homely to us, so also does *baris* = bere, barley. *Ahs*, an awn or *ear* of corn, and *ahana*, chaff, mean lit. the little sharp thing, Lat. acus, a needle.

Animals.—Beast in general is *dius* = deer ("rats and mice and such small deer," Shak.); wolf and fox occur under these names. Worm, as in O.-Eng., means a serpent or dragon, cf. Great Orme's Head. Bird in general is the Bible word *fowl*. Sparrow (*sparwa*), dove, and eagle are named, the first two, as in Eng., but in the passage, "Where the carcase is, there are the eagles gathered together," eagle is *ara*. This word, now lost, is the O-Eng. and Sc. earn or erne and Ger. Adler = Adel-aar, the noble bird. The O-Eng. erne exists as a surname, *e.g.* Dr. Arne, the famous musician. Thomas the Rhymer says:—

> "The raven shall come, the *erne* shall go,
> And drink the Saxon bluid sae free."

For the domestic animals, cattle generally is *faihu*, a widely diffused word, lit. the tethered; it is our fee. In Barber's Brus it has its original meaning:—

> "In the contrie thar wonnyt ane
> That husband wes and with his *fe*
> Oft-syss hay to the peile led he."—Book x. 150.

Ox, the carrier (cf. veho), is *auhsus*, retaining the original guttural. Our ewe, Lat. ovis, is found in *awe-thi*, a shepherd, and *awi-str*, a fold. Ulfilas uses in "Behold the Lamb of God!" the word *withrus*, our wether, lit. a yearling. Horse is not in the Gospels, but the Runic *aihwus* (horse) is in aihwa-tundja, the burning-bush, the first member of which is cognate with ὠκύς, swift, acer, and the latter part our *tinder*. In O.-Norse ehwa and in A.-S. ehu mean horse. In such a compound it should be noted that horse simply means large, cf. horse-chesnut, and ἱππο-κάνθαρος, horse-beetle or

* Cf. Sans. Anna, lit. what is eaten for ad-na (root ad), food in general, *rice.*

monstrous beetle. This old term for horse is found in Burns in the form of aiver, *e.g.*—

> "Yet aft a ragged cowte's (colt) been known
> To mak a noble *aiver*;
> Sae, ye may doucely fill a throne
> For a' their clish-ma-claver."—*A Dream.*

The *noble aiver* here turned out to be George IV. The glossary says of the word, an old horse, which makes the poet far from complimentary. One other singular animal name is in Ulfilas. The Baptist was clad in camel's hair (Ga-wasiths taglam ulbandaus). The Go. for hair is *tagl*, our word tail. *Ulbandus* is for καμήλος, and the wonder is how such a word came into the language. It has a long and interesting history. In Greek it is ἐλέφας, our elephant, in A.-S. olfend, the camel, in Lat. ebur, ivory, for this was known in the west long before the animal. The first part of *Alphabet* leads us to the Semitic form, Heb., aleph and eleph, the ox, and ibâh, the elephant. For the old alphabets were hieroglyphic or pictorial in origin. The true Teutonic alphabet—the Runes—was of this nature, and the letters had names. Ulfilas based his characters on Runes, as modified by Greek and Latin. The first letter-name in these was, as in the Phœnician alphabet, the ox, the Go. faihu, and its symbol can still be seen in our F. Another is called Tius = ↑ = T, the Teutonic Jove, wielder of the thunder-bolt, and still in Tues-day. The symbol is just the broad arrow or sapper's mark. What was struck by his bolt must be *deo-datum*, confiscated, and thus Government serves itself heir to his thunder. But, to return to *Ulbandus*, el-eph contains the Arabic article el or al. The second syllable is one of many Sanskrit names for the elephant, *ibha* = the strong one, and the appearance of the term in the west is due to the Arab traders who from the very early times shipped the animal and ivory from Ceylon. *Ibha*, again, is the Gr. adverbial suffix and adv. ἰφί, and it does the same duty in Go., where adverbs are regularly formed from adjectives by adding—aba, *e.g.*, baitr-aba = bitterly, abr-aba = ably. In O-Eng. we have the Romance oliphant, still a surname. Chaucer, in his own tale as poet of the Canterbury pilgrimage, sends the Quixotic knight Sir Thopas to do battle with the giant Sir Oliphaunt.

III.—MAN AND HIS ACTIVITIES.

Occupations.—As might be expected, the Ulfilic vocabulary is rich in terms of agricultural life. Ploughing is the Bible word *earing* (ar-jan); plough itself—our word is not Go. but

Slavonic — is *hoha* = hoe (cf. Sc. howk, and Eng. hew, hue), *gau-ja*, a peasant, is the Aberdonian gudge, familiar to readers of "Johnny Gibb." Warlike terms are *har*-jis, an army in the sense of a destroying host, as in harry, herr-ing (moving in vast shoals); ga-*drauhts*, a soldier, lit. one who serves, from a Go. verb (driugan), still in Sc. dree, in the old expressive phrase, to dree his wyrd, or meet his fate, in *droch* and its equivalent *dwarf*; *weigan*, to fight, and *wig*, a warrior, are in Wallace wight, wage and vie.

Civil Life.—The Goths called themselves as a nation Gut-thiuda, the root of which is the Indo-Eur. *tu*, to swell, be large or mighty, as in Lat. tu-mor, tu-ber, tu-eor, and in Eng. in thu-mb, the thick one, der Diche. A monarch is *kindins*, from the same stem as king. *Reiks*, the Hindoo rajah, Lat. rex, is very common as ruler, Ger. Reich and *ric* in bishop-ric, and in drake (duck-king). The most frequent term of respect, and always applied to our Lord, is *frau-ja* = Κύριος, now quite lost, but common in the ballads as free.

> "No longer durst I for him let,
> But furth I fundit (went) with that *free*."
> —*As I went on ae Monday.*

—The editor of the ballad remarks:—*Free*, fey, lord, or fairy, and thus gets over a difficulty with a little courage. This word may be the curious Norse surname Fridge, seen on tombstones in the north, and freyr, the O. Norse equivalent of frauja, gives here a better explanation of the surname of Frier than the Romance friar. The refined arts of healing and teaching are illustrated by *lekeis*, a physician, the O. Eng. leech, lit. the licker, and by *laisari*, Ger. Lehrer, which Ulfilas uses for rabbi. The root is in a Go. pret. verb *lais*, I know, and its derivative therefore means one who makes to know. *Lais* is lore, and Sc. lere.

Religion.—The Supreme Being is *Guth* God, peculiarly Teutonic, and of uncertain origin. Ulfilas refrains from using the Runic Tius. A demon is *skohsl*, Ger. Scheu-sal, Sc. shoo, cf. monstrum. But a commoner term is *un-hultha*, Devil, Satan, still in Ger. un-hold, unkindness, sin, and Held, a hero, hence the favourite O.-Eng. name Hilda, the gracious one. Hell is *halja*, the covered or hidden, cf. Hades, the unseen. The root is in *hul*-jan to cover, Sc. hool of a pea, and the hulls of "Sartor Resartus." A priest is a *gud-ja*, or good man. The affix ja is very common as a diminutive in Sc., and specially Aberdeenshire, *e.g.*, wifie, lassie. In this connection may be noted an odd expression that throws light

on the ceremonial of Go. worship. When our Lord entered the synagogue at Nazareth on Sabbath He stood up to read, in Gr. ἀνέστη ἀναγνῶναι, in Go. us-stoth siggwan bokos = stood up to sing the book. Again, a certain lawyer asked, "Master, what shall I do to inherit eternal life?" "What is written in the law? How readest thou?" replied the Master. The Gr. is simply πῶς ἀναγνώσκεις, but Ulfilas says Hwaiwa us siggwis? how outsingest thou? Wherever Scripture reading occurs this verb *siggwan* is met with. Our word *read* is also in Go., but in the sense of speaking. All this points to the custom of hearing the lessons read in a kind of recitative or chant during the ordinary church services.

The foregoing terms give, in considerable variety, evidence of the social and intellectual condition of the Goths. They also bear out the fact that these people were, in a veritable sense, our forefathers. A further inquiry will prove that these remains throw a very instructive light, not only backward upon the primitive condition of Teutonic Europe, but forward on many words and expressions still in common use. As we have a fuller and richer history, and an older and more varied literature than any other European country, it cannot but happen with our words, as with our institutions, that old friends assume new faces. Gothic, therefore, serves to show how great has been this change in meaning as well as form. The long-forgotten sense in which they occur gives us a strange surprise. *Sutizo* comp. of suts = sweet, is in Matt. xi. 24—"Sweeter [*i.e.*, better] will it be for Sodom at the judgment-day than for thee." Again, Mark xi. 12, coming out of Bethany the next day, Jesus was greedy *(gredags) i.e.*, hungry. *Sels*, our silly, always retains its good sense, as in Ger. selig, happy, blessed. In the parable of the talents, Matt. xxv. 26, "Thou wicked and slothful servant" is "Un-selja skalk jah lata," lit. unsilly, skulk, yea, late, four words equally good Go. and good Eng., but in a strangely altered sense. *Lats* = late is always used in the sense of lazy. *Modags* = moody is always angry, thus, "Whosoever is moody (modags) with his brother without a cause." Verbs show similar changes of sense. *Slahan*, which has now the special sense of slaying, in Go. means simply striking. Thus, at the Crucifixion the bystanders say, "Prophesy who is slaying [striking] thee," "Hwa ist sa slahands thuk." This sense is old Scotch.

"Dintis,
That slew fyr as men slayis on flintis."—*Barber.*

In the cricket-field a hard hitter is a slogger, retaining the old guttural. To *whet* is now obsolete almost, but Ulfilas regularly uses it in the sense of threaten, rebuke. Thus Our Lord whets the evil spirits. *Wopjan* = weep, has now quite a restricted sense, but in Go. it is used for calling aloud under all circumstances, of cock-crowing, and of the voice of the Baptist. The usual word for crying in our sense is *gretan* = greet. Thus Peter went out and grat bitterly (gaigrot baitraba). Again, in Ulfilas the thieves twitted *(id-weit-jan), i.e.*, reproached, Jesus on the cross, from a verb the same as Sc. wite = blame. *Ween*, now only in over-weening, is quite common in its old sense of expect, fancy. "Art thou he that should come or ween [*wenjan*] we another?" asked John's disciples. *Be-wray*, now obsolete, is *wroh-jan*, to accuse, *e.g.*, "Wrohiths was fram thaim gudjam" = was accused of the priests.

This process of change goes a step farther, and introduces us to common Go. words of which scarcely a trace now survives. Go. *ogan*, to be in extreme fear, has been frittered down to the senseless expletive awful, yet at one time it meant death by throttling (root, *agh*, to choke, Lat. anguis = the throttler). Its derivatives are ogre, eager, ugly, awe. *Theihan*, to thrive, prosper, gives the commonest asseveration in O.-Eng. "So mot I the" = so may I prosper. The thigh, Sc., the, is the plump, well-thriven. *Laikan*, to dance and play, *laiks*, sport, is the vulgar *larks*, *larking*. The brother of the Prodigal, coming near the house, hears singing and larking (laikins). *Dugan*, to avail, is Ger. taugen, common in O.-Sc. as dow ("The dowie dens of Yarrow"), and still a surname Duguid = Ger. tüchtig = doughty. The root lives in a mutilated form in, How d' you *do?* Doughty is also the familiar Sc. term dawtie. *An-an*, to breathe, a very old verb, is lost in Eng. *Uz-an* is said of Our Lord giving up the ghost on the Cross. Scotch long preserved the word—

> "And thai war *ayndles* and wery
> And thar abaid thair *aynd* to tan."—*Barber.*

Anst = grace, favour, Ger. Gunst for ga-anst is a pretty metaphor in Gothic. It is the name Anstey = Gracie.

German is in a much more archaic and homogeneous condition than modern English, and, therefore, one is quite prepared for many points of connection between it and Gothic. But they belong to different branches of the Teutonic family; in fact, *while* it has the richest literature on philology, it is as a language

the least suitable type of a Teutonic tongue to study. Gothic, a Low-German speech, is more akin to Dutch and Scotch. Here one finds the most astonishing identities, not alone in form and sense, but in pronunciation and minute turns of expression. The Goth said hwan, than, nu, ut, na, ain, haim, braid, gagg, for when, then, now, out, no, one, home, broad, go. For "Suffer little children to come to me," Ulfilas says, but slightly changed, "Let thay bairns gang to me." A hypocrite is a liuta = one that loots. The Apostles, sent out to preach, are to take ain rung (one staff, aina hrugga). One is to lay upon the altar as a gift a hunsl = hansel, Shakespere's "unhouseled" in Hamlet. The disciples take of the fragments twelve baskets full of brock (ga-brucko). The leaven of the Pharisees, Gr. ζύμη, Lat. fermentum, is called *beist*, from beitan, to bite, in Scotland known as the first milk of the cow after calving. "Blessed are the merciful," or *bleiths* = the blate = coy, modest. St. Luke tells Theophilus that he has followed the Gospel story glegly *(glaggwus)*, or accurately (ἀκριβῶς), from the beginning. The gospel mystery again was concealed from the wise and prudent and revealed to babes. For babes here we have *niu-klahs* = new-born. Can this be the klekkin and klekkit, familiar to every Sc. laddie that has kept rabbits? The homeliness of the expression is almost shocking, but in language, as in life, there are plenty of poor relations. The hireling shepherd in the parable is betrayed by his "stibna *framaths*," his fremmit or strange voice. The Gadarene demoniac is *wods* = mad, Sc. wud, on which Shakespere puns in Midsummer Night's Dream,—"Wood within the wood," scarcely intelligible to southron readers. Another Shakespearian phrase—"The wild waves whisht"—in the Tempest, is paralleled in Go. by the very Sc. expression "Jah warth *wis* mikil" = and there was a muckle wheesh, following our Lord's rebuke of the waves. Other peculiar terms oddly survive in Sc. Thus, James and John were partners —*ga-dailans*—of Simon, a word used with precisely the same force among our herring fishers, who go as dealsmen and half-dealsmen. A common asseveration is "bi sunja," the verily of our version. Quite a long story might be told of this word and its cognates; enough to say it lives in "My san!" a variant of "my certe!" and may be the vulgar Eng. "Upon my Sam!"

Turning now to verbs we find similar evidence of identity. The Goth said bide *(beidan)* for staying in a place. Jesus asks of the unbelieving generation, How long must I thole *(thulan)* you?

Bartimæus, now no longer blind, throwing off *(af-wairpands)* his robe and loupin up *(us-hlaupands)*, cam at (to) Jesus. The elect are the waled *(waljan)* or chosen. The crown of thorns—wipja us thaurnum—is a wuppin o' thorns, from *wipjan*, to twist or plait, the Sc. wup, beautifully used in the ballad of Sir Patrick Spens:—

> " Gae fetch a wab o' the silken claith,
> Anither o' the twine ;
> And wap them in til oor gude ship's side,
> And let na the sea come in."

The regular verb in Go. for the act of perception is *gaumjan*, the expressive Sc. gumpshin. For a strictly mental act Ulfilas uses *hugjan*, to think, which, with the particle of reversal, *for*, Ger. *ver*, is Sc. for-hoo, to forsake, as in "Johnny Gibb," " I wadna say nor the laird wud hae to forhoo's bit bonny nest." To strike or cuff with the open hand is *kaupat-jan*, Sc. gowpen. Finally, *giutan*, to pour out water, is quite a Sc. favourite, and developed curious meanings such as *gyte* = silly (cf. Lat. ef-futio from the same root). In "Johnny Gibb" is "Loshtie, man, ye're seerly gyaun gyte;" and again from an old poem :—

> " Wark, ye ken yersels, brings drouth,
> Wha can thole a gaisen mouth ? "

When we turn from the vocables of a language, as evidence of its character and pedigree, to its grammar we are on firmer ground. For in the one case the materials are in a perpetual flux, each district, generation, social set, individual even, giving a new meaning to the old stock or borrowing from without, whereas in the other we have the permanent bed of the stream, deeply grooved with the flow of ages. In language, as in the features of Nature, age conceals itself under the guise of familiarity. Who thinks, as he follows the course of some wimpling burn, that he is gazing on what is older than the oldest historical monument in existence, or dreams that the variations of case and number in his own speech were evolved in an age long anterior to the Vaidic hymns. For these are the grammatical formulæ of his race, perennial as the very laws of thought. Historical grammar is in the study of language what morphology is in the natural sciences treated biologically. In both directions we see persistency of type, co-existent with endless modifications in obedience to the demands of functional growth and *decay*. Thus, what seem to be arbitrary formulæ, mere atrophied

structure, become in the light of historical grammar natural and significant. Many of the so-called anomalies of English grammar can thus be invested with meaning and interest. The historical grammarian has not evidence enough to give us the ultimate analysis of those conventional formative elements—number, person, and case; but he can tell us why one says *methinks*, but a child may not say *me likes nurse;* why an Englishman's *like I do* is wrong, but his *give 'em* (not for *them*) *it* right; why *drownded* and *once-t* are as correct as *sounded* and *whilst;* and why a Scotchman uses *hit* for *it*, and speaks of a *cattle beast* and a *widow woman*. The answer to these and many more such questions is found better in Gothic than anywhere else, for this reason that it places us so near to the primitive type of Teutonic speech, undisturbed by subsequent functional derangement. Hence it is indispensable to the scientific study of English grammar.

It would be impossible, within reasonable limits, to give anything like a full account of Gothic grammar. Merely a few points can be selected, and these such as prove the essential identity of the language with our own, and at the same time elucidate modern idiom and expression. Gothic is, like German, highly inflected. Ulfilas cannot equal the richness of the Greek verb, but he is able to convey to his countrymen with sufficient accuracy the spirit of so subtle and flexible a language. The basis of conjugation is the familiar distinction between strong and weak verbs, or what might rather be called primary and derivative. Gothic properly makes this turn on what is the cardinal function of the verb, the expression of preterite or past time. The primitive and very natural mode of doing so is by reduplication of the root, and this is well preserved here as in Greek. Traces of the process exist in Latin, either obvious, as cado, ce-cidi, or disguised, as fac-io, fec-i for fe fac-i. Our did, Go. *di-da*, is the sole English survival of this process, but we have several specimens of the feci-type, as hold, held (Go. hald, hai-hald), take, took (têk, tai-tôk), Sc. greet, grat (grêt, gai-grot). This process must have become at an early period merely conventional, as the rule in Gothic is not to repeat the root-vowel but the initial consonant and a uniform light vowel, ai = e, in met. Even at this early stage the further step had been taken, and many verbs originally reduplicating are treated as now; *e.g.*, Go. bind, band = bind, bound; sit, sat. This is the result of a shifting of the accent due to the addition of personal endings, similar to what we see in photográph, photógraphy, cáput, capitís. Hence

have arisen the monosyllabic preterites that we find in Go., Ger., and Eng. These processes exhausted themselves ages ago. Not a single strong verb has been developed within the historical period. The younger weak and derivative inflection supplies our increasing wants, and, like Jacob, appropriates the heritage of its elder brother. We say helped, dragged, slipped, for example, for the Go. halp, drôg, slaup. A Scotchman even says *begoud* for began, and, still worse, *seen* for saw. It was a Glasgow merchant, they say, who, visiting the Louvre, remarked in answer to his French conductor's "This is a portrait of Burke, your great countryman," "Ou, ay mon; I seen him hanged."

But the best proof of the value of Gothic as an aid to historical grammar is to be found in the analysis it renders possible of our weak preterites in -d and -ed. There we see that they are really compounds, like will go, am walking, &c. The auxiliary *do* has coalesced with the stem, so that I love is just I love-did. The Go. *tam-jan*, to tame, has for its past—

S.	P.
tam-i-da	tam-i-dêd-um.
,, dês (for dedt)	,, ded-uth.
,, da	,, ded-un.

Strange to say, the very common Teut. verb to do is not found as a separate verb in Gothic. It must have reduplicated and formed its pret. as S. di-da, di-des, di-da: Pl. di-ded-um, and so on. The first syllable disappears when used as a compound tense. It thus appears that, even where apparently we see tense indicated in Eng. by modification of the stem, we really use an auxiliary. Gothic uses this composite tense as freely as we do now. At the grave of Lazarus Jesus wept (ἐδάκρυσεν), which Ulfilas renders, "Jah tagrida Jesus," as if we were to say, and Jesus teared. In Matt. xxvii. 1, "That they might kill him," is "Ei af-dauthi-dedeina," reminding one of what the child said of the murdered fly, "Me deaded it."

This preterite tense is the only *time* inflection in Gothic. In common with all the Teut. languages it had no future. Ulfilas renders the Greek future variously, most frequently by using the subjunctive. In Latin, as every boy knows, the Fut. Ind. and Pres. Subj. of some conjugations are perplexingly like each other. Ulfilas also uses the Indic. and Part. Present, as I coming heal him = *Ik quimando* gahailja ina, for I coming will heal him; "Thai

guth gasaihwand," *i.e.*, they seeing God, for they will see. Circumlocutions he employs, just as we may now say, I am going to, about to, intend to, have to. Our auxiliaries shall and will are always independent verbs in Gothic, with the decided meaning of duty and wish. Such is the tense condition of the Teutonic verb; the other forms which grammarians parade in Eng. are simply imitations of Latin. All this goes to show that in primitive times little advance had been made in developing this, one of the subtlest and most abstract of conceptions. Even yet the commonest errors in translation, as every teacher knows, are due to confusion of tenses.

Many more striking illustrations of the value of Gothic to the student of grammar might be adduced. Suffice it to refer to one more verbal form, the passive. Here Gothic throws a unique light on the primitive condition of the Teutonic tongues. These all, like Eng., never had a conjugational or simple passive. We are so familiar with it in Greek and Latin that we can scarcely realise our poverty here. In point of fact, young learners have the greatest difficulty in grasping the conception of a passive. They fail to see the difference between *I am struck* and *I am sick.* For in every case the participle, in a compound tense, which we call the main verb, is nothing more than an adjective in predicative relation to the subject. English, and still more French and German, avoid the passive by the use of indefinite and reflexive pronouns. Thus, *the book has been found*, is in German *the book has found itself.* Colloquially we regularly avoid the passive by using the indefinite *they* as a subject. Other modern languages adopt to an excessive extent reflexive forms. Thus, Italian has for *it is said, it says itself.* Even Gothic preserves merely a trace of a passive inflexion by simple derivation from the stem as *bairada, bairanda* (from bairan, to bear) = φέρεται, φέρονται. But the favourite mode is our modern one of circumlocution, with participles and auxiliaries, or by a peculiar formation from a passive participle in—*na*, our— en in brok-en. Thus, from *mikils*, Sc. muckle, *mikilnan* to be enlarged, from *hauhs* = high *hauhnan*, to be exalted. Slight traces of this still survive in *learn* and *own.* The former is from an original *lais-nan*, to be lered or taught. German shows this distinction of act. and pass. senses well in *lehr-en* (active, to teach), where h is not radical, and *lern-en*, to be taught, to learn. *Own*, again, is an original agnan (A.-S. ag-nian) to be possessed, from aigan to have, owe.

These forms are, however, not true passives, being simply the participle with the adjectival ending — na or en, treated as a verb, very much as we still do, *e.g.*, "Fallen, thy throne, O Israel!" or = Fallen's thy throne, O Israel! In all these cases the participle is merely an adjective used predicatively. *I am loved* is not a form like *amor*, but really *I am (one) loved.*

The ultimate elements in grammar are two-fold, verbal and pronominal. In a now-forgotten book, the "Diversions of Purley," Horne Tooke showed a century ago that nouns, which bulk so largely in grammar, are merely epithets formed from verbal roots. It is said that our *man*, the thinker, is the only case of a Teut. root used directly as a noun. The pronominal elements are the abbreviations of speech, in themselves non-significant. Their inflexion, as pronouns, is peculiar. We have lost many of the Gothic forms, but keep a few, *e.g.*, the old dative in -m, as him, them, whom (found also in seldom, whilom), and the neuter of demonstratives in -t, as it, that, what. The masc. accus. sing. in -na one hears in Sc. *thone*, not a mistake for *yon*. Thus Peter, in his denial, said, "Ni kanna thana mannan" = I kenna thone man. The full form of I, Go. *ik*, has quite gone. In King Lear, the disguised Edgar, using the Somersetshire dialect, says, "Keep out, *che vor' ye*," Go. ik warja thuk = I warn you. When the two disciples are told to find the colt in the village over against, Ulfilas uses the dual of the pronoun, for Go. had a dual here as well as in the verb. A more serious loss is that of the reflexive, which German preserves.

Turning, lastly, to demonstratives and relatives, we find still further interest in Gothic grammar. The article is exactly what we see in Sanskrit and Greek. Its feminine survives in *she*, its neuter as *that*, which Sc. treats as an article, *e.g.*, "Gie me that poker," for "Give me the poker." The nom. plur. of *that* (which is not *those*) we use as the old plur. of *he*, but in Sc. it is rightly used, as Go. thai bokos = Sc. thay books. The proper plural of *he* Chaucer uses regularly. In Shakespere its dative is frequent, though his editors substitute for it *them*. It is not in Gothic, except in a few adverbial phrases, such as to-day (himma daga). The relative is very imperfectly developed. The correlation of adjectival clauses is effected mainly by the addition of an indeclinable particle *-ei* to pronouns and demonstratives, as ik-ei = I who. This is just what might be expected, for the use of the relative *implies a distinct* advance in composition and the inter-dependence

of clauses. Its growth is always slow, and the usage of cognate tongues is far from uniform. The reader of Dickens knows that when the uneducated attempt to go beyond the rudimentary stage in composition of ands and buts and wells, and aspire to relatives, they throw about their which's very freely. The primitive relative is usually a pronominal particle (Go. *-ei* above is the Sanskrit *ya*), or the article, the indeclinable *the* (our article) of A.-Sax. and the abbreviated *that* or *'at* of Scotch, due, in the opinion of Dr. Murray, not to Norse but Celtic influence. Barber writes:—

> "James of Douglas his menye than,
> Sesit weill hastily in hand
> *At* (for *whom*) thai about the castell fand."

This relative one constantly hears in Scotch. In such imitation Scotch as Burns often wrote we have *wha* instead. Thus, "Scots wha hae" would be in Barber "Scottis at hes," as Dr. Murray well shows. Our forms—who, which, that—have an interesting history. *That* is simply the demonstrative, and has its own appropriate use; but who, whose, whom, what, which, are really interrogatives. They are so in Sanskrit, where who is *ka*, as in Gaelic still. Sans. and Gr. clearly differentiate relative and interrogative, not so Lat. *Who* as a relative in Eng. was not recognized by Ben Jonson, the author of our earliest English Grammar, who says "one relative *which*." Dr. Furnivall says it was first used once in Wyclif's Bible, and very sparingly till Shakespere. In Gothic the interrogative is *hwa-s*, Sc., whaw; its instrumental *hwê* we have in *why*. *Which* is a descriptive form of adjectival relationship quite distinct from *who*—Lat. qualis, Fr. lequel, Ger. der welcher, and Shakespere's the which, all show this peculiarity. Gothic proves it to be a compound, where it is *hwi-leiks*. The first member is *wha*=wha; *leiks* is the word for body, as in Lich-field, lich-gate. This is our *like*, both separately and in composition, as in life-like = lively. For it has become our general adverbial suffix, -ly, *e.g.*, like-ly = like-like. Sanskrit affords a curious parallel; Lat. *corpus*, a body, is the Sans. *kalpa*, which also forms adverbs in the sense of like, but not quite, *e.g.*, pandita-kalpa = a quasi-pundit. Scotch people similarly use like in making explanations, *e.g.*, He gie'd it to me like; I gaed wi' him a mile like.

The following table exhibits the pronominal compounds of *like*, to which Sc. adds thi-lk = that-like:—

Gothic.	*Scotch.*	*German.*	*English.*
Hwi-leik	hwi-lk	we-lch(er)	whi-ch.
Swa-leik	swi-lk = sic	so-lch(er)	su-ch.
Ana-leiks	i-lk and ilk-a	a(h)n-lich	ea-ch, on-ly.

The foregoing imperfect sketch of this fascinating subject is an attempt to tell the strange story of the Gothic MS. and its enlightened author, of the people among whom he laboured, and of the sad fate that has buried them in oblivion. On the fragmentary evidence of the Gospels, excluding altogether the Epistles, I have endeavoured to illustrate the intellectual condition of the Goths in the fourth century, and to prove that whatever there is in the language of to-day that we regard as most homely and familiar, the indispensable materials of everyday intercourse, and the very formulæ under which our thought must find expression, all lived in the mouths of our remote Gothic ancestors in their rude *tuns* and *burgs* by the banks of the Danube, while this land of ours was still a Roman colony. Do such records not awaken a deeper interest than a blurred footprint in the Red Sandstone, or even an inscribed brick from a Chaldæan mound? Jacob Grimm, the father of comparative philology, found in Gothic the clue to many of his researches, and based upon his study of it those principles which have illuminated the whole field of linguistics. During the half-century that has intervened—this is the Jubilee year of the completion of his great Grammar—philologists have never lost sight of the value of Gothic. The Ulfilic remains have appeared in various forms, but the field has been almost entirely left to German scholars, and this in spite of the fact that their language is, for many reasons, the furthest removed from the true type of a Teutonic speech. The English Universities are strong in classical philology, but in every other department the German easily holds the field. The best Celtic dictionary and grammar, the most complete collection of Anglo-Saxon literature, the only concordance to Shakespere worthy of the name, the most complete English grammar,—these, among many other works, have been left to the foreigner. Bosworth gave us a text of the Gothic Gospels, Professor Skeat has done much to popularise the study, and quite recently Mr. Douse has published a very elaborate and very scientific treatise of about 300 pages, which he facetiously calls an Introduction to Gothic, though it is unintelligible to any one who *has not* worked long and well at the subject. But the surprising

feature is that, whereas German scholars, men of much the same class as our secondary schoolmasters, have so successfully prosecuted such studies, and Englishmen only in a fragmentary fashion and generally under the mantle of the universities, Scotchmen have contributed nothing to the subject, yet they possess an unbroken stream of literature from Bannockburn to the days of Burns and Scott, and, what is of more importance, they have, not from books or the mistaken theories of teachers, but as a living product, native to the soil that bore them, a rich system of phonetics, a homely pithy vocabulary, and a genuine Teutonic idiom, vastly more archaic than the academic and conventional printed speech of the English scholar. To the Scot, therefore, the language and idiom of our old writers and of Ulfilas have a freshness, a directness, and a meaning which are scarcely possible to any but an exceptionally favoured Southron. In proof of this contrast take two such works as Barnes' Poems in the Dorset dialect and the Banffshire tale of "Johnny Gibb." Whereas the one must be almost a foreign tongue to the average Englishman, no intelligent Scot, especially if born and reared in a country district, need miss in the other one point of its inimitable humour, its pithy, pawky turns of idiom and expression, and the real genius that created its character and incident. But, alas! in spite of such advantages of Scottish scholarship, Dr. Johnson might still say of it that everyone here gets a mouthful but no one may make a meal of learning. Such works as "Johnny Gibb" and the invaluable inquiry of Dr. Murray into the dialects of the South of Scotland are something to be proud of. They have done infinitely more for the study of our fast-decaying vernacular than all our schools and colleges, our St. Andrew's and Burns' clubs put together. To the philologist a vernacular is vastly more instructive than any mere book-speech, for it is in the field of dialectic growth and decay that the real problems of language are to be studied. In such fields there is almost everything to be done for our own vernacular. Who will do for the north-eastern counties, for Fife and the Lothians, for Lanark and Ayr, what Dr. Murray has so well done for the Scotch of the Border Counties? Is Jamieson, even in his latest form, a scientific record of our vocables? Is Irving's history of the literature worthy of the subject? The late lamented Dr. Ross, of the Edinburgh High School, worthily followed in Irving's track, but the field is not yet nearly surveyed. Or, to come to less ambitious ground, is there not room

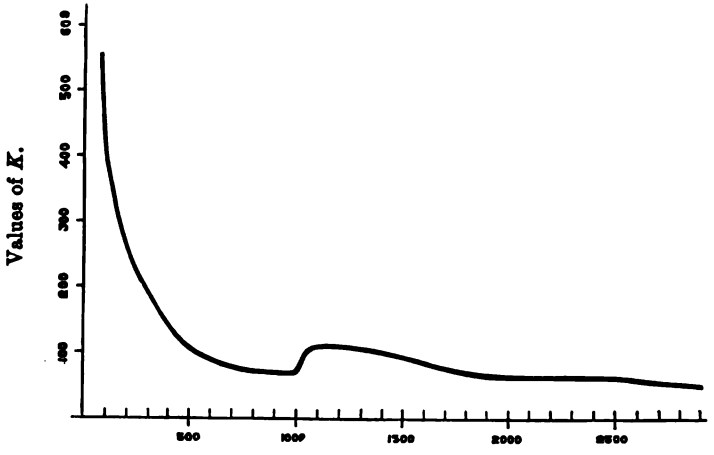
for some scholarly account of Gaelic, Norse, and French influence on Scotch? Who will treat philologically the relics of the oldest vernacular in burgh and parliamentary records, the diction of our folk-lore and ballad minstrelsy, and even of Burns and Scott, or popularise our national epic, Barber's Brus? Whoever should attempt to cultivate any one of these spheres of linguistic research will render his labours more valuable by a previous acquaintance with the Gothic of Ulfilas.

XVIII.—*Approximate Formulæ for the Motion of Projectiles.*

By PETER ALEXANDER, M.A.

[Read before the Mathematical and Physical Section of the Society, 30th November, 1886.]

ABOUT a year ago my attention was directed to this subject, and I found that the formulæ and tables in use are all based on the supposition that the resistance of the air to the motion of a projectile through it is proportional to the *cube* of the projectile's velocity. Now, as I understand that scientific men are in general agreed that the resistances of fluids to the motion through them of bodies with great velocities are proportional to the *squares* of their velocities, I was led to examine the subject carefully. In a text-book of gunnery, by Captain G. Mackinlay, R.A., I found a table (II.) of the value of K, the coefficient of resistance, for the cubic law, to ogival-headed projectiles ($1\frac{1}{2}$ diameter heads), extracted from "Bashforth's Motion of Projectiles," which shows that K is not a constant, but varies considerably and in a very peculiar way with the velocity, which is indicated by the annexed diagram (Fig. 1), which is a rough copy of one given at page 78 of



Velocities in feet per second.

Fig. 1.

Captain Mackinlay's text-book, in which the horizontal co-ordinates represent velocities, and the vertical co-ordinates represent the values of K corresponding to these velocities.

I concluded from this that the cubic law was not even approximately correct. I therefore transformed Bashforth's table from the cubic law to the law of squares. The values of k in the transformed table are roughly indicated by the annexed diagram (Fig. 2), which shows that k is practically constant for velocities

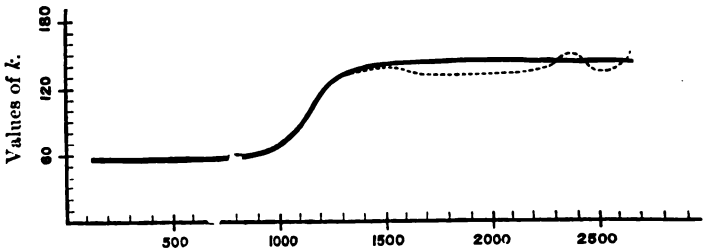


Fig. 2.

below 800 feet per second, and that is it also practically constant for velocities above 1,400 feet per second—the second constant bearing to the first the ratio of 7 to 3. As the velocity increases from 800 feet per second to 1,400 feet per second the value of k increases by about 11 per cent. of the original value per 100 f. s. of increase of velocity between 800 f. s. and 1,000 f. s. From this velocity to 1,100 f. s. k increases by 71 per cent. of its original value. Between 1,100 f. s. and 1,200 f. s. the increase of k is about 23 per cent. of its orignal value. Between 1,200 f. s. and 1,300 f. s. the increase of k is 16 per cent. of original value; and from 1,300 f. s. to 1,400 f. s. the increase of k is 9 per cent. of original value. For velocities above 1,500 f. s. the value of k varies slightly, sometime decreasing and sometimes increasing, as is indicated in a rough and exaggerated way by the dotted line in the diagram. Those latter variations must, I think, arise from slight imperfections in the original observations. The reason why k increases from 800 f. s. to 1,400 f. s. appears to be because the bullet, besides overcoming the ordinary resistance, produces waves of compression in the air, which travel outwards laterally from the bullet. This being known, a rough estimate of a mean value of k for the solution of any given problem may be easily made.

Again, the formulæ connecting time and velocity and space and velocity (for the cubic law) namely:—

$$\frac{1}{v^2} - \frac{1}{v_o^2} = 2\,kt \qquad (1)$$

$$\text{and} \quad \frac{1}{v} - \frac{1}{v_o} = ks \qquad (2)$$

are acknowledged by the text-books to be practically useless for the solution of problems, owing to the difficulty of selecting the proper mean value of k; consequently all the problems are solved by the use of tables laboriously constructed for the purpose.

Also, it is acknowledged that no tables can be constructed connecting space and time, and they have therefore to be linked together by the relations of each to velocity. Now, while I would not be understood to depreciate the value of the methods involving the use of these tables, I think it is a pity that some rough methods of calculation should not be taught which might be used in the absence of these tables.

I have not examined (1) and (2) to see if convenient approximations may be derived from them, as they are acknowledged to be, *even in their accurate form*, practically useless in the solution of problems. I therefore turned my attention to the formulæ founded on the law of squares, and found that good rough approximations could be got from them.

The accurate formulæ are—

$$v = \frac{v_o}{1 + kv_o t} \qquad (3)$$

$$v = v_o e^{-ks} \qquad (4)$$

$$\text{and} \quad ks = \log_e (1 + kv_o t) \qquad (5)$$

These formulæ themselves are very practically useful if logarithmic tables are accessible, but in the absence of such tables the following approximations, derived from (3), (4), and (5), will be found to give roughly good results:—

$$\left.\begin{aligned} v &= v_o\,(1 - kv_o t) \\ t &= \frac{v_o - v}{kv_o v} \end{aligned}\right\} \qquad (6)$$

$$\left.\begin{aligned} s &= v_o t\left(1-\frac{1}{2}\,kv_o t\right) \\ t &= \frac{s}{v_o}\left(1+\frac{1}{2}\,ks\right) \end{aligned}\right\} \tag{7}$$

$$\left.\begin{aligned} \text{and} \qquad v &= v_o(1-ks) \\ s &= \frac{2\,(v_o - v)}{k\,(v_o + v)} \end{aligned}\right\} \tag{8}$$

If the problem be to find the range and final velocity of a projectile fired at a given elevation with a given velocity, the vertical motion will determine the time of flight, which, being determined, (6) and (7) will determine the final velocity and range.

In the case in which the elevation is small, as it usually is, the vertical motion will differ little from that in vacuo. Hence—

$$t = \frac{\text{twice the initial upward velocity.}}{g} = \frac{2\,\mathrm{V}\sin\alpha}{g} \tag{9}$$

Where V = Vel. of projection.
and α = Elevation.

If the elevation be not very small—

$$t = \frac{1}{\sqrt{kg}}\left\{ \tan^{-1}\left(\sqrt{\frac{k}{g}}\cdot \mathrm{V}\sin\alpha\right) + \log_e \tan\left[\frac{\pi}{4} + \tfrac{1}{2}\tan^{-1}\left(\sqrt{\frac{k}{g}}\mathrm{V}\sin\alpha\right)\right]\right\} \tag{10}$$

or, roughly—

$$\left.\begin{aligned} t &= \frac{2\mathrm{V}\sin\alpha}{g}\left\{1-\frac{1}{2}kh'\right\} \\ \text{where } h' &= \frac{(\mathrm{V}\sin\alpha)^2}{2g} \end{aligned}\right\} \tag{11}$$

As far as I can see, the most important problem in practical gunnery is the following:—Judging the distance of an object to be S, and its elevation to be ϕ, at what elevation must the bullet be projected to strike the object?

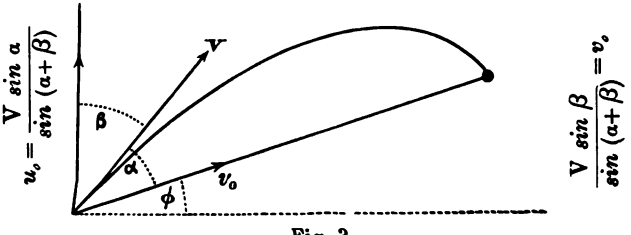


Fig. 3.

Supposing α to be small, we have from (5) and (9)—

$$\frac{2u_o}{g} = t = \frac{e^{ks} - 1}{kv_o}$$

$$\therefore \quad 2ku_ov_o = g\,(e^{ks} - 1)$$

$$\text{or} \qquad \frac{2k\,V^2 \sin\alpha \sin\beta}{\sin^2(\alpha+\beta)} = g\,(e^{ks} - 1) \qquad (12)$$

Now, since α is small, we have—

$$\beta = \frac{\pi}{2} - (\alpha + \phi)$$

$$= \frac{\pi}{2} - \phi \text{ nearly} -$$

$\therefore$ (12) becomes—

$$\alpha = \frac{g}{2k\,V^2}\,(e^{ks} - 1)\cos\phi \text{ nearly} - \qquad (13)$$

or roughly—

$$\alpha = \frac{gs}{2\,V^2}\left(1 + \frac{1}{2}ks\right)\cos\phi \text{ nearly} \qquad (14)$$

or— $\alpha = \alpha_o \cos\phi$

where— $$\alpha_o = \frac{gs}{2\,V^2}\left(1 + \frac{1}{2}ks\right) \qquad (15)$$

α_o being the elevation which will give the range s on a horizontal plane, and α the elevation to give the same range on a plane inclined ϕ to the horizon.

In conclusion, I ought to give the means of determining k. The smaller constant value of k is about—

$$\cdot 00006\frac{d^2}{w},$$

and the greater constant value is—

$$\cdot 000147\frac{d^2}{w},$$

Where d = Diameter of bullet in inches,
and w = Weight of bullet in lbs.,

the bullet being ogival-headed, the radius of the curve being $1\frac{1}{2}$ diameters. (Fig. 4.)

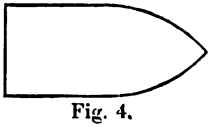


Fig. 4.

For other shapes of bullets the value of k would have to be found by experiment.

XIX.—*How to use the Polariscope in the Practical Determination of Internal Stress and Strain.* By PETER ALEXANDER, M.A.

[Read before the Mathematical and Physical Section of the Society, 3rd February, 1887.]

I DO not mean to give a detailed scientific explanation of the theory of light, but, with a view to make my remarks understood by those who have either not studied the subject or have forgotten it, I must make a few remarks thereon.

The following quotation from Spottiswoode's "Polarization of Light" is very clear and concise:—"It is considered as established that light is due to the vibrations of an elastic medium, which, in the absence of any better name, is called ether. The ether is understood to pervade all space and all matter, although its motions are affected in different ways by the molecules of the various media which it permeates. The vibrations producing the sensation of light take place in planes perpendicular to the direction of the ray. The paths or orbits of the various vibrating ethereal molecules may be of any form consistent with the mechanical constitution of the ether; but on the suppositions usually made, and none simpler have been suggested, the only forms possible are the straight line, the circle, and the ellipse. But in ordinary light the orbits at different points of the ray are not all similarly situated, although there is reason to believe that in general the orbits of a considerable number of consecutive molecules may be similarly situated; yet in a finite portion of the ray there are a sufficient number of variations of situation to prevent any preponderance of average direction.

"This being assumed, the process of polarization is understood to be the bringing of all the orbits throughout the entire ray into similar positions. And in the case of the tourmaline plate, the orbits are all reduced to straight lines, which consequently lie in one and the same plane. For this reason the polarization produced by tourmaline, as well as by most other crystals, is called rectilinear,

or, more commonly, plane polarization. This property of tourmaline may also be expressed by saying that it permits only rectilinear vibrations, parallel to a particular direction, determined by its own internal structure, to traverse it."

A ray of light is analogous to a series of pulses of transverse vibration, travelling along a stretched cord or wire. If the particles of the cord vibrate in straight lines all in one plane, the series of waves is analogous to a ray of plane polarized light. If the particles of the cord vibrate in stationary elliptic orbits similar to each other and similarly situated, the set of waves will be analogous to a ray of elliptically polarized light. If the ellipses have equal axes they are circles, and the set of waves is analogous to a ray of circularly polarized light. If the particles vibrate in elliptic (including circular and rectilinear) orbits, the ellipses not being stationary, but rotating about the line along which the waves are propagated, the set of waves will be analogous to a ray of ordinary light. This motion of the ellipses in their own planes, about a line perpendicular to their planes, is called *apsidal* motion, and, as a consequence of the propagation of this motion from particle to particle of the cord or medium, the ellipses will not be similarly situated, but the whole series will form a surface which will be the same as that of an elliptic cylinder which has been twisted uniformly about its axis.

If two lines be chosen perpendicular to each other and to the line of propagation of the vibrations, any set of pulses of transverse vibration is equivalent to two simultaneous sets of transverse rectilinear vibrations parallel, respectively, to the two chosen lines, that is to say, to two rays of plane polarized light travelling together having their planes of vibration perpendicular to each other.

When a ray of light enters an æolotropic transparent substance it is usually resolved into two rays of plane polarized light vibrating in planes perpendicular to each other, parallel to the directions of greatest and least elasticity of the substance. The exceptions to this are those in which the ray was plane polarized, and had its plane of vibration parallel to the axis of greatest or least elasticity of the substance before entering the same, in which cases the ray suffers no change except, perhaps, a change of direction.

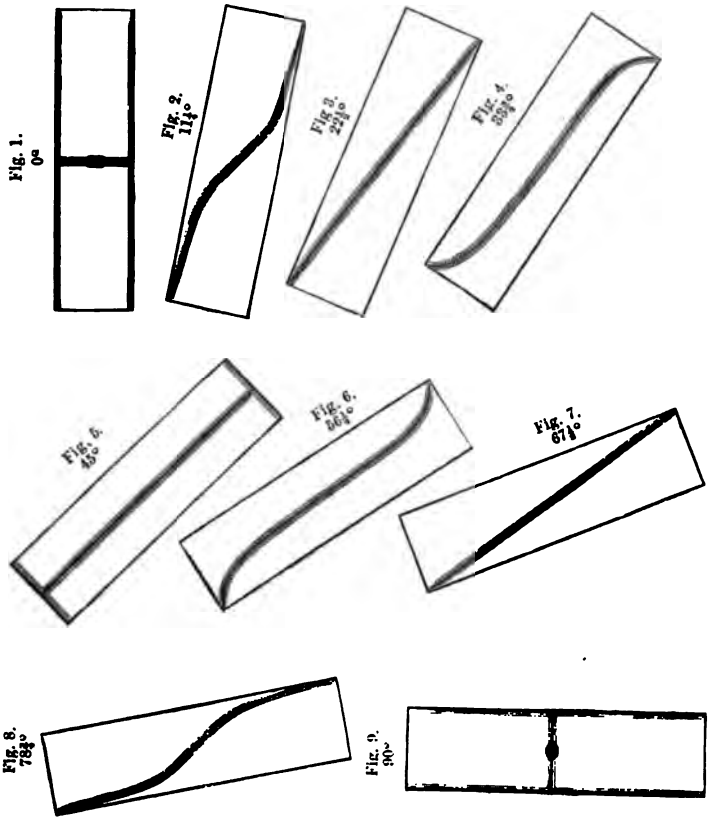
A polariscope consists of two parts, namely—a polarizer and an analyzer. The polarizer changes a ray of common light into a ray of plane polarized light, by suppressing one of the two

component plane polarized rays which the former is equivalent to. The analyzer may be the same as the polarizer, but its function is different. It is used to examine the nature of a ray of light entering it.

If the polarizer and analyzer be similarly situated, the ray of light which has been polarized by the former will pass unchanged through the latter. If, now, the analyzer be rotated about its axis through a right angle, it will suppress the ray which has been polarized by the polarizer, and darkness will be the result. Again, if a plate of æolotropic transparent matter, with parallel faces, be introduced between the polarizer and analyzer with its faces perpendicular to the ray passing from the former to the latter, the ray will in general suffer a change, because its component plane polarized rays, with vibrations parallel to the directions of greatest and least elasticity of the introduced plate, will travel through the plate with different velocities, and therefore the one will suffer retardation relatively to the other. Consequently the resultant ray which leaves the plate will not in general be the same as that which enters it, and therefore when it enters the analyzer it will be resolved into two components, one with its vibrations parallel to those of the ray which leaves the polarizer, and the other with its vibrations perpendicular to those of the former, and the analyzer will suppress the former component, but will allow the latter to pass through it. Hence the light will be partially restored. Should, however, the plate be introduced with its axis of greatest elasticity or least elasticity parallel to the vibrations of the ray leaving the polarizer, it will allow the ray to pass through unchanged, and consequently the analyzer will entirely suppress the ray, and there will still be darkness.

If the plate be not very small, and if instead of a single ray of light we have a cone or sheaf of rays, it may happen that at some parts of the plate the direction of greatest or least elasticity is parallel to the direction of the vibrations of the rays, and at other parts not so, which will be the case if the lines of stress in the plate are curvilinear. Should this be so, the whole plate will appear luminous, except along certain lines, which are the *loci* of points at which the axis of greatest or least elasticity is parallel to the vibrations of the rays leaving the polarizer, which lines will appear black. If the plate be now rotated about a line through its centre and perpendicular to its faces, the black lines will assume new positions in the plate.

To illustrate this, I shall show you the black line in a rectangular bar of glass subjected to stress, similar to that of a beam supported at both ends, and uniformly loaded throughout its length. You will observe that when the length is parallel to the direction of vibration of the polarized ray, the black line lies along the upper and lower edges of the bar, and perpendicularly crosses the middle of the bar, as is indicated in Fig. 1.



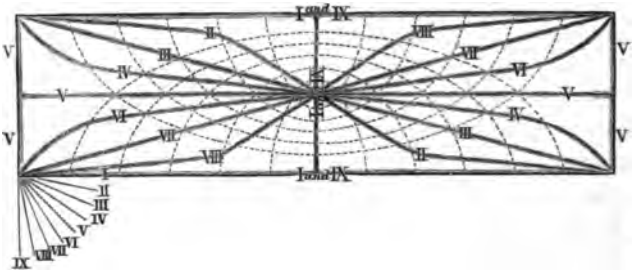
Figures 1 to 9 show the forms and positions of the black line for various positions of the bar, from the horizontal position to the vertical position.

It will be observed that the central point of the bar is *always* black, consequently we conclude that there is *no* stress there.

At every other point of the black *loci* lines of stress cross them horizontally and vertically, that is to say, parallel and perpendicular to the direction of vibration of the polarized ray.

If we wish to draw lines of stress we can do so as follows:—Draw all these black *loci* in one rectangle on a piece of cardboard as in Fig. 10.

Fig. 10.



Let the card be mounted so as to be capable of rotation about a horizontal axis passing perpendicularly through the centre of the rectangle. Let the card now be rotated slowly about this axis, and simultaneously let a tracing point (Fig. 11), carried round with the card, move horizontally so as always to cross each black *locus* at the instant when the rectangle is in the position corresponding to this *locus*. The line thus traced on the cardboard will be approximately a line of stress. By this method a network of lines of stress can be drawn in the rectangle on the cardboard. This network (Fig. 10) will show what is the state of internal stress of the glass bar and consequently that of the uniformly loaded beam.

The black *loci*, I., II., &c., correspond to the angular positions, I., II., &c., of the card. The dotted lines are the lines of internal stress.

A more accurate way of drawing the lines of stress is to rotate the card in front of the lantern simultaneously with the rotation of the glass bar, so as always to have the image of the glass bar occupying the same position on the card, and let the tracing point, while carried round by the card, at the same time move horizontally, so as always to be on the black *locus* projected on the card. The line drawn in this way will be an accurate delineation of a line of stress. This motion of the tracing point may be accomplished as follows:—Let the tracer be a small toothed wheel, T,

capable of rotation about a fixed axis, A A′, at the end of a tracing pen, P, and let a heavy load, W, be attached rigidly to the pen at the end of a rod, D, so as to compel the axis, A A′, of the tracing wheel to be vertical when in use.

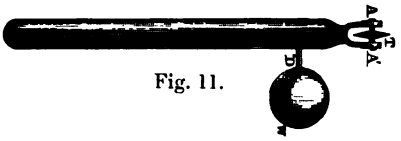


Fig. 11.

The tracing point will thus be incapable of any motion but that communicated to it by the rotation of the card, and the horizontal motion given to it by the rotation of the tracing wheel as the tracing point is made to keep on the black *locus*.

I append a rough drawing of the instrument by which I imitate the stresses to which parts of structures are subjected :—

Fig. 12.

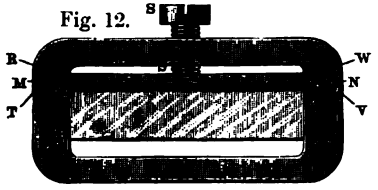
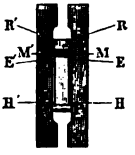


Fig. 13.

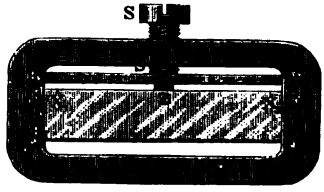
Fig. 14.



Figures 12 and 14 are side and end elevations, and Fig. 13 a plan of the instrument. E F K H denote the glass bar, R W a brass bar which receives the pressure from the screw S S′ and communicates it to the glass bar through bits of india-rubber, such as M N, interposed between the brass and glass. Fig. 13 shows the screw at the top of the instrument by which the pressure is communicated. Fig. 14 shows the openings at the end through which the bars of glass and brass are introduced. P P′ and Q (Fig. 12) are pins upon which the ends of the glass bar are supported. If we wish to imitate a beam fixed at the ends we must introduce other pins, T and V, above the ends of the glass bar. Fig. 12 is intended to indicate the arrangement for imitating a beam supported at both ends and subjected to a uniformly distributed load. This is approximately imitated by introducing

a long strip of rubber, E F, between the brass and glass bars. To imitate loads applied at isolated points of the beam, I introduce little narrow bits of rubber at these points between the glass and brass. For example, Fig. 15 shows how I imitate the stress of a beam loaded at its centre and supported at its ends, by introducing a little bit of rubber, Z, between the brass bar, R W, and the glass bar E F K H, right under the screw S S'. Uniformly bending stress may be imitated by introducing little bits of rubber between the brass and glass at X_1 and X_2.

Fig. 15.



Other forms of stress may be similarly imitated.

The black *loci* can easily be studied by turning the apparatus round with the hand in an ordinary table polariscope, but in the lantern polariscope the rotation must be communicated by a contrivance similar to that which rotates the lantern kaleidoscope.

The idea of turning the study of these black *loci* to practical use for the determination of the state of internal stress of parts of a structure was suggested to me some three or four years ago by a civil engineer, Mr. James Love, who was superintending the manufacture of certain works by a Glasgow firm for a London firm of civil engineers. His hopes of the usefulness of the method were so great that he entered on a systematic study of higher mathematics and optics, so as to be able to work it out.

I have lost sight of Mr. Love, but I have thought the matter out, and this is the result divested of mathematical symbolism.

XX.—*On a Double Chain of Electrical Measuring Instruments to measure Currents from the Millionth of a Milliampere to a Thousand Amperes, and to measure Potentials up to Forty Thousand Volts.*

By Sir WILLIAM THOMSON, F.R.S., Past-President.

[Communicated to the Society at a Meeting held in the Natural Philosophy Class-Room, University of Glasgow, 20th April, 1887.]

A FUNDAMENTAL requisite of a measuring instrument is that its application to make a measurement shall not alter the magnitude of the thing measured. When this condition is not fulfilled (as is essentially the case with an electric measuring instrument not kept permanently in or on the electric circuit or system to which it is applied), it is the magnitude as influenced or modified by the measuring instrument which is actually measured, and the measurement is to be interpreted on this understanding, whatever may be the circumstances. Suppose, for example, the thing to be measured is the diameter of a fine wire, or of the carbon filament for an Edison-Swan lamp, or of a hair, or of a silk fibre. If the measurement is made by a microscope, with the proper optical apparatus for measurement, the thing measured is absolutely unaltered by the measuring appliance. But if the measurement is made by an ordinary screw gauge, or by any other mechanical fitting appliance, however gentle, it is impossible to avoid some diminution of the diameter to be measured by the pressure of the measuring appliance, which introduces some slight uncertainty even in the measurement of steel or copper wire, and very considerable uncertainty when a filament of softer material is to be measured.

The nearest approach in electric measuring instruments to the fulfilment of this condition, of not altering the magnitude of the thing measured, is attained by the electrometer when applied to measure differences of potential between different points of a wire, or metallic mass of any shape, in which electricity is kept flowing by a battery or dynamo or other electro-motive apparatus. The insulation of any practical electrometer is so nearly perfect that

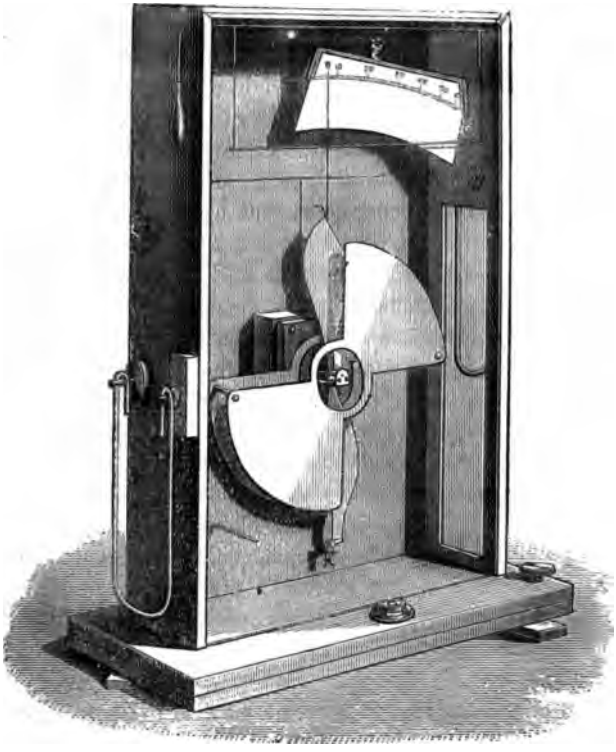
the conduction of electricity through the instrument does not sensibly diminish the difference of potentials of the points touched by the electrodes. In this respect, therefore, the electrometer would be ideally perfect; but, alas, it is only for potentials of more than 400 or 500 volts that the electrometer in any shape has been made a convenient and fairly-accurate standard measuring instrument for ordinary practical use. For less than 400 volts the practical solution in connection with electric lighting is afforded by a current-measuring instrument with a known resistance in its circuit; though for many differential measurements, and particularly for measurements of the insulation of submarine cables, and determinations of the insulating quality of insulators for many practical purposes, the quadrant electrometer is found useful as a differential measuring instrument.

The quadrant electrometer in its most sensitive adjustment indicates about $\frac{1}{100}$ of a volt, and with modified adjustments (heterostatic and idiostatic) can be used for measuring up to 300 or 400 volts. It is described in detail in the "Report on Electrometers and Electrostatic Measurements" published in the British Association volume for 1867 (Report of the Committee on Electrical Standards), and reprinted as Article XX. of my "Collected papers on Electrostatics and Magnetism," so I need say nothing more of it at present. The Electrostatic Voltmeter exhibited and shown in action this evening, and represented in the annexed drawing, is an idiostatic standard instrument for measurement of from 400 volts to 10,000 volts.

It consists of an air condenser with one of its plates capable of a to-and-fro motion so as to vary the capacity of the condenser. The fixed brass plates are supported so as to be accurately parallel to each other and in metallic connection, while they are thoroughly insulated from the case of the instrument. The movable plate is of aluminium, and is supported in a vertical position on a knife edge, the plane of its motion being parallel to the fixed plates and situated midway between them. The upper end of this movable plate has a fine prolongation which serves as a pointer for indicating the deflections on the scale of the instrument, and at its lower end is fixed a knife edge having its length perpendicular to the plane in which the plate moves.

There are two pairs of terminals, one pair for the fixed plates and the other pair for the movable plate, and each terminal is insulated from the case of the instrument. Of the pair on the

left-hand side of the case, the terminal towards the back of the instrument is in metallic connection with the fixed brass plates,



while that towards the front (which may be called the working terminal) is simply an insulated brass pin. A glass U-tube is suspended between these two terminals, and contains a safety-arc of finest copper wire connecting them. The terminal toward the back of the instrument on the right-hand side is in metallic connection, through the V-groove support, with the movable plate; in other respects the pair of terminals on the right is similar to the pair on the left.

In order to save time in taking readings an arrangement is provided for checking the oscillations of the movable plate, and stops are placed to limit its range and prevent damage to the pointer.

When the fixed and movable plates are connected, respectively, to two points of an electric circuit, between which there exists a

difference of potential, the movable plate tends to move so as to augment the electrostatic capacity of the instrument, and the magnitude of the force concerned in any case is proportional to the square of the difference of potential by which it is produced. In the use of the instrument this force of attraction is balanced by the horizontal component of a weight of any convenient amount hung on the knife edge at the bottom of the movable plate.

The scale is graduated from 0 to 60, and the divisions represent equal differences of potential, the actual magnitude of the difference per division being dependent upon the weight in use at the time. A set of three weights is sent with each instrument, of, respectively, 32·5, 97·5, and 390 milligrammes, providing for three grades of measurement in the proportion of 1 : 2 : 4. Thus the instrument shows one division per 50 volts with the link (the lightest weight) alone on; one division per 100 volts with the medium weight hanging on the link, and one division per 200 volts with all three weights on.

At from 8,000 to 10,000 volts there is some liability of a spark passing between the movable plate and one or other of the four fixed quadrant plates between which it moves, hence the highest potential for which the instrument can be used is about 10,000 volts. For higher potentials my long-range electrometer ["Collected papers on Electrostatics and Magnetism," §§ 383-384] is, so far as I know, the only standard electrometer which has hitherto been practically used. But with the experience which I have had of gravity instruments for electric balances in general, and particularly of the electrostatic voltmeter, I am now convinced that an electric balance for weighing the direct attractive force between a fixed plate and a movable disc will be the best form of standard electrometer for all potentials exceeding 8,000 or 10,000 volts. I hope before the close of next session to be able to show to the Philosophical Society a convenient instrument of this kind, adapted to measure from 10,000 to 40,000 volts, and possibly even to 70,000 or 80,000 volts; although I cannot anticipate for measurement of such high electric potentials any great practical demand, as far as the future of electric technology can be conjectured at present.

The electrometer is available with equal convenience for the measurement of electric potentials in circuits of direct current or of alternate current. In the latter application the result is quite definitely the square root of the time average value of the square

of the difference of potentials between the points touched by its electrodes. A good deal is now being done for electric lighting and the electric transmission of power by means of circuits at high potentials of from 700 to 2,000 and 3,000 volts; and for such purposes the electrostatic voltmeter, just described and illustrated, is conveniently available. The method of finding potentials by measurement of current through a known resistance is also available even for these very high potentials, but the electrometer is preferable, because of the cumbrousness and expensiveness of the resistance coils required by the current-measuring method when the potential is more than 600 or 700 volts.

For potentials of from 500 volts downwards the method of measuring current through resistance is thoroughly convenient and practical. Thus we are led to the consideration of the current-measuring branch of our "Two-branch" chain of measuring instruments.

Beginning with the feeblest currents, I may refer to the astatic mirror galvanometer of the form introduced by me about twenty-eight years ago, and now much used for laboratory and telegraph-testing. This instrument is capable of being adjusted to measure currents as low as the fifty millionth of a milliampere with a coil of from 5,000 to 10,000 ohms. It has, besides, the great advantage that its sensibility can be easily varied through a wide range. Thus an instrument, which, when in its most sensitive state, will measure the fifty millionth of a milliampere, can be easily arranged to measure the thousandth of a milliampere. Professor S. P. Langley, of the Allegheny Observatory, U.S., recently used in his radiation experiments one of these instruments which he had specially made, and which included several important improvements of his own, such as the use of a very long suspending fibre and a very perfect mirror. He finds an instrument of 20 ohms resistance capable of being used with perfect accuracy for the measurement of the two millionth of a milliampere. In ordinary telegraph-testing these galvanometers are commonly adjusted to measure currents down to about the millionth of a milliampere, and for special tests, as, for instance, the measurement of the insulation of short lengths of core for submarine cable, sensibilities as high as those specified above are often used.

The current-measuring instrument, commonly called by the name of galvanometer, whether it be the sine galvanometer, the tangent galvanometer, or any of the different varieties of mirror

galvanometers in use is essentially magneto-static. That is to say, it is an instrument in which a controlling magnet is used to balance the electro-magnetic force produced on a magnetised steel needle by a conductor or coil through which flows the current to be measured. In the sine galvanometer and tangent galvanometer, as originally used, and as still largely used for many important electrical measurements, the controlling magnet is the earth; but it is only in a locality far from dynamos and from wires carrying continuous* currents for electric lighting, that the terrestrial magnetic field suffices for a sine or a tangent galvanometer when any approach to accuracy is required: and thus in telegraph offices, workshops, and engine-rooms it is generally desirable, if not absolutely necessary, to use a much stronger magnetic field than that of the earth for controlling the needle of a galvanometer. But whether the controlling magnet be the earth or a steel magnet its force is essentially inconstant: and, therefore, a magneto-static galvanometer of any kind requires some means for determining, from time to time, the coefficient by which the absolute value of the current measured can be calculated from its indications, or a means of freshly adjusting the field to give any convenient absolute value to the readings on the scale of the instrument.

Sixteen or seventeen years ago I introduced a form of tangent galvanometer which came to be called the "paddle wheel galvanometer," from the appearance of the two coils being somewhat like the paddles of a paddle steamer. In this instrument two coils, adjustable to any desired equal distance on the two sides of the centre, act on a small needle or group of small needles hung by a single silk fibre, and carry a pointer of about eight centimetres length, which shows deflections on a scale of unequal divisions proportional to the tangents of the deflections. Ordinarily the needle is acted upon by the terrestrial magnetic force alone, but sometimes in laboratory experiments a controlling magnet is placed either to augment or to diminish the controlling force on the needle. This instrument, though capable of considerable accuracy for absolute measurement in a locality free from local magnetic disturbance, was replaced by my graded galvanometers,† which have been found much more convenient for general purposes and

* The neighbourhood of a conductor carrying an alternate current for electric lighting, however strong, would not disturb the terrestrial magnetic field for a sine galvanometer or tangent galvanometer in its neighbourhood.

† *Patent No.* 5,008, of 1881, 26th December.

have been somewhat largely used since they were brought out five years ago. I have never, however, been quite satisfied with them, and I have been incessantly occupied in the attempt to produce an adjustable magneto-static tangent galvanometer which shall be both more convenient for ordinary use, and more susceptible of high accuracy for scientific investigation than the graded galvanometers. I am not able this evening to show more than a half-finished attempt to realize this object, but I feel that I am now nearly touching it, and I hope at the commencement of next session to be able to place before you a working instrument of the magneto-static class, which shall be thoroughly convenient for showing the number of lamps a-light at any time in an ordinary dwelling-house lighted by Edison-Swan lamps with direct current, and which shall also be available as a scientific measuring instrument to measure currents of from one to sixty amperes with a proportionate accuracy of one quarter per cent. in the best part of its scale.

I have also made great efforts during the last six years to produce satisfactory constant-standard instruments for measuring electric currents, and I have from time to time placed before you results in which the object was to some degree realized, but, as I have always told you, not satisfactorily. This time last year I placed before you and explained instruments depending on Faraday's discovery of the tendency of a globe, or cube, or short bar of soft iron, to move from places of weaker to places of stronger force in a magnetic field.* Two of those instruments which you saw, and which were then nearly completed, are indicating the potential of the current by which we are lighted this evening. You see when I increase the potential between the terminals of the instrument (by taking out lamps in multiple-arc between the electric light mains), how the indicator shows—now, an augmentation of $2\frac{1}{2}$ per cent. which makes the lights considerably brighter; now, again, a diminution of 1 per cent.; and, again, the previous potential, and the lights as they were. Since you first saw them these two instruments have been incessantly at work on the electric-light wires in my house and laboratory, and have done good work all this time. I may say, in passing, they have allowed me to use much higher incandescence without risk to the lamps than would have been practicable without a trustworthy potential

* Patent No. 11,106, 9th August, 1884.

indicator, and personal, if not automatic, attention to regulate the potential according to its indications.

Though, however, they have so far been practically useful to myself, I am not satisfied with the instruments, because they involve the use of soft iron, the retentiveness of which is always a serious trouble that I have only been able to keep within bounds, not completely to eliminate, by the use of the current reversor which you see in connection with one of the instruments before you. I have, therefore, returned to the original discovery by Ampere of the mutual force between movable and fixed portions of an electric circuit, first utilized by Weber in his "Electro-dynamometer," to obtain a constant-standard instrument for measuring electric currents without any of the trouble and residual inaccuracy entailed by the use of soft iron. After many trials, I have succeeded in improving an electro-dynamic balance towards which I made a great many trials five years ago; and within the last three months I have succeeded in my laboratory in making accurate measurements of currents of from 20 milli-amperes to 200 amperes, by means of four instruments, on the general plan of the rudimentary centi-ampere balance before you, in which a single movable coil is repelled and attracted upwards by two fixed coils, one below it and the other above it, and the total of the electro-magnetic force is balanced by a weight hung on a knife edge attached to the balance.* At the commencement of next session I hope to show you some of these instruments in a state fit for practical work. In the meantime, I can only thank you for the patience with which you have listened to me this evening, and for the kindness with which now, as on previous occasions, you have allowed me to bring half-done work before you, and to tell you of what I hoped to do, but had not yet done, in the way of producing practically useful instruments.

---

* Patent No. 2,028, 21st April, 1883.

XXI.—*The Reform of our Present Methods of Disposal of the Dead: Earth-to-Earth Burial* versus *Cremation.*

By EBEN. DUNCAN, M.D., President of the Sanitary and Social Economy Section.

[Read before the Society, 27th April, 1887.]

THE question of how our great cities are to dispose of their dead has now come to be, both from the sanitary and from the economical point of view, a question of the first importance.

The credit of first arousing public attention to the necessity for a reform of the burial customs of this country is due to Mr. G. A. Walker, a London surgeon, who published in 1839 a book, entitled "Gatherings from Graveyards," a detail of dangers and fatal results produced by the unwise and revolting custom of inhuming the dead in the midst of the living. Mr. Walker brought forward a mass of evidence which proved that the overcrowding of the graveyards and church-vaults of London had rendered their vicinity pestilential. He showed that the graves were systematically violated, and the remains of the dead treated as offal, and cast aside in order to make room for fresh interments; and he demanded that the Government of the country should prohibit the interment of the dead in the vicinity of the living, and that the cemeteries of England should be put under stringent regulations to prevent a recurrence of evils which had led repeatedly to serious outbreaks of epidemic disease. A verse from the poet Henry Kirk White is quoted on the title-page of Mr. Walker's book, which shows that the evils of which he complained were lamented and denounced forty years previously:—

> "And who would lay
> His body in the city burial-place,
> To be thrown up again by some rude sexton,
> And yield its narrow house another tenant
> Ere the moist flesh had mingled with the dust,
> Ere the tenacious hair had left the scalp,
> Exposed to insult lewd and wantonless?
> No, I will lay me in the village ground,
> There are the dead respected."

Three years after Mr. Walker's book appeared, a Government inquiry was made into the practice of interment in towns. This

report contained evidence of a similar nature. Again, in 1850, an inquiry was made into the state of burial grounds by the Board of Health, and a report was presented to Parliament, showing such a dangerous and revolting state of matters in our city graveyards that the Government was at last roused to action, and in 1852 was passed what is known as the Burials Act. This Act put it in the power of local authorities to shut up, or regulate all the graveyards which were "constructed in such a manner as to be dangerous to health, or offensive, or contrary to decency." The duty of providing cemeteries for the people was laid on the Parochial Boards and Burgh Councils, which were empowered to take ground for that purpose.

In 1855 the Secretary of State for the Home Department issued Regulations for the Burial Grounds under the Burials Act. After providing for the fencing and draining of the ground, for the division of it into grave-spaces, and for the registration of graves and burials, he laid down the following rules, to which I wish to direct your special attention:—

1. The grave-spaces for the burial of persons above 12 years of age shall be at least 4 feet by 8 feet, and those for the burial of children under 12 years of age 4 feet by 5 feet, or 4½ feet by 4 feet.

2. One body only shall be buried in a grave at one time, unless the bodies be those of members of the same family.

3. No unwalled grave shall be reopened within 14 years after the burial of a person above 12 years of age, or within 8 years after the burial of a child under 12 years of age, unless to bury another member of the same family, in which case a layer of earth, not less than one foot thick, shall be left undisturbed above the previously-buried coffin.

4. No coffin shall be buried in any unwalled grave within 4 feet of the ordinary level of the ground, unless it contains the body of a child under 12 years of age, when it shall not be less than 3 feet below the level.

These regulations were drawn up in the light of the experience of the sanitary authorities not only of England, but of every other country in Europe. They are in accordance with the views of those best fitted by their experience of such matters to judge as to what is necessary to prevent a cemetery from becoming a source of nuisance and danger to the living.

Again, in 1867, there was fresh legislation which dealt with the subject. In the Public Health (Scotland) Act of that year it

is enacted that "Any churchyard, cemetery, or place of sepulture, so situated, or so crowded with bodies, or otherwise so conducted as to be offensive or injurious to health, may be treated as a nuisance, and shut up, or regulated, on satisfactory proof being led before the Sheriff by the Local Authority of the place in which the graveyard is situated."

In order to complete the statement of the law of burial, it is necessary to point out that, according to the Parochial Ecclesiastical Law of Scotland, every parishoner has a right to a grave in the parish churchyard, with the proviso that his right is only a temporary one, limited to the time during which his body remains recognisable in the soil. The law of Scotland does not recognise a grave in a parish churchyard as a spot to be permanently tenanted by any one inmate, but as the temporary resting-place of successive occupants and successive generations. When the interred body has, by the process of decomposition, been resolved into dust, the law deems the grave vacant, and the space may be re-allocated to a new occupant. The precise time in which the right to re-allocate a grave can legally be exercised varies according to soil, size of body, and nature of coffin;—18 to 25 years have been spoken of in Duncan's Treatise on the Parochial Law of Scotland, which I am told is a standard authority in such matters of Scotch law. This right can only be exercised by the heritors if there is no unoccupied ground fit for allocation. When, from the increase of the parochial community or other cause, the burial accommodation of the parish is too limited, the heritors are bound to supply additional ground. Under the Burials Act, the local authorities have unfortunately been granted the power of contracting with a cemetery company, not under the Burials Act, to bury for them the bodies of persons who would have had rights of interment in the burial grounds of the parish.

Private cemetery companies have been originated in our large cities to provide for the graveyard accommodation of the community, provision for which had been neglected by the public bodies, which ought to have provided it under powers of the Burials Act of 1855. The shares in these companies were eagerly taken up by the commercial classes, because it was known that large profits could be realised. In graveyards, as in house property, the greatest profits are extracted from the pockets of the poor. These profits are got because the cemeteries so provided by private enterprise are not under the regulations of the Burial Grounds

Act. Although originated by humane and public-spirited citizens, they are now conducted on purely commercial principles, and are permitted to ignore laws of sanitary science and considerations of public decency, to which, were they under a public censorship, they would be compelled to attend.

Although some of the grosser insanitary conditions connected with vault burial and city churchyards have been removed, the facts which I shall narrate are, I think, sufficient justification for the assertion that in the suburban areas of our large towns the duty of the local authorities under the Public Health Act, to see that the cemeteries under their jurisdiction are conducted without offence to health and decency, is either very imperfectly performed, or not attended to at all.

In the year 1866 the Town Council of Glasgow appointed a committee to obtain information as to the condition of intramural interment in the city. The committee found that the intramural graveyards were all situated either in direct contact with, or in the immediate vicinity of, a densely-crowded working population, and that many of them were so crowded with bodies that the soil was utterly unequal to the task of absorbing and neutralising the noxious exhalations from the dead. The committee asked the Council to get this whole system of impurity swept away, as there could be no doubt that the existence of such burial grounds was injurious to the public health. A petition was presented to the Sheriff, in 1870, to have these graveyards closed or restricted, and a decision was got, ordering the said burial grounds to be closed after the 7th May of that year, with the proviso that existing lairholders might still inter upon a grant being given by the Sanitary Department after proper inquiry into the circumstances of the case.

In 1876, a report was made to the Town Council by Mr. Macleod, of the Sanitary Department, on the condition of the fourteen city burial grounds, which had either been closed altogether or placed under restriction by order of the Sheriff. In his report he says that these places are apparently managed without any regard for the feelings of respect and reverence with which the living desire to bury their dead, and that, with one or two exceptions, the grounds were overcrowded with bodies and had been allowed to fall into a disgraceful state of weeds, disorder, and dilapidation, which must have had a most depressing and *demoralising* effect on the minds of the unfortunate inhabitants

of the surrounding houses. He recommended that further interment in them should at once be discontinued and forbidden.

In addition to these places, which are now almost entirely disused, there are still four unrestricted intramural public cemeteries: the Necropolis, the Southern Necropolis, Janefield, and Sighthill, all of which are comparatively recent and contain a small area of unallocated lairs. These places are at present well cared for, and kept in good order. There are also five extramural public cemeteries on the outskirts of the city: Dalbeth, St. Peter's, and Sandymount, on the North side, and Craigton and Cathcart, on the South side of the Clyde. If these cemeteries were under the Burials Act, or administered in accordance with the rules laid down by the Secretary of State, they would very speedily be filled. Mr. Macleod calculated that, giving the prescribed space for each body, and assigning a separate grave for each interment, 13 acres annually would be required for the inhabitants of the city, and to meet the wants of the suburban residents we may add 3 acres more; so that, without providing for any increase of the population, as 19,000 deaths may be taken as the annual number for greater Glasgow, 130 acres would be alienated from the use of the living every 10 years to accommodate about 19,000 dead bodies. That is the ideal graveyard accommodation, which, as far as the poor are concerned, is a very remote ideal. Out of 19,237 interments which were made in the cemeteries of Glasgow in the year 1875, 9,627 bodies were buried in common ground; 2,000 of these would represent the average pauper interment, and the rest consisted of poor persons who could not afford to pay more than the 10s. or 12s. which gives them the use of the fifth part of a grave, or the sixtieth part of a pit, as the case may be.

I shall describe to you the burial of the poor in the common ground of three cemeteries which I have personally inspected. I shall begin first with a most respectable cemetery, called the Southern Necropolis, owned by the lairholders, and managed in their interest. There are here and there in the eastern portion of that cemetery small patches of ground which have not been taken up by private lairholders. In these patches a pit is dug about 4 feet broad, 7½ feet long, and 8 feet deep. Into this pit a double row of adult coffins is placed, one built on the top of the other like bricks in a brick wall, with a few inches of sand between, until the pit contains its full complement of eight adult

coffins. As these coffins do not fill up the whole of the grave, the space left is filled with infants' coffins and those of young children, so that there may ultimately be 16 or more in one common grave. During the time that the coffins are being built into their places, the only medium for absorbing the offensive gases from the decomposing dead, is the stratum of three or four inches of sand on the top of the coffin lids. The grave is not filled up with earth until the pile of coffins reaches to within 3 feet of the surface of the ground. It remains an open grave, the top of it covered with a few loose planks, sometimes for a week, sometimes for 10 days, or longer, according to the rapidity with which the supply of coffins comes in. The gravedigger, from whom I got my information, admitted that in the summer time it was not possible to keep down the smell in that part of the graveyard.

Of the extramural cemeteries, I have looked at Sandymount and Dalbeth. In Sandymount the system of filling up the common ground differs, in respect that only one grave-space is dug at a time, and that there is no attempt at covering the lid of the last pauper's coffin. One coffin is piled on the top of another until the grave is filled up to within 3 feet of the surface, then, and not till then, the grave is covered up and a new grave dug, at the distance of 12 inches, alongside the newly-filled one. The rows of piled coffins go on increasing rapidly. At the time of my visit, two common graves were open, one of them waiting its last occupant, and the other just ready to be filled. These graves were estimated to accommodate 5 adult coffins, or a much larger number of children. At Dalbeth burying ground a large area is already filled with burial-pits of larger size and more numerous occupants. Last week I saw a new pit opened on the slope of the ground near the river. The soil was damp clay. The pit measured $7\frac{1}{2}$ feet square and 12 feet deep. At the time of my visit, it contained about 10 or 12 adult coffins and a large number of little ones. The coffins were lying in the bottom of this damp clay-hole, quite uncovered, not even boarding on the top of it, and I was informed that it would remain so until it was built up to within 3 feet of the surface, when it would probably contain about 30 adult coffins and as many children's. Already, at the time of my visit, the smell from the decomposing corpses had become very disagreeable, in fact the whole neighbourhood of the pit smelt badly. Although not usually very sensitive to such smells, the very funeral undertakers cry out *against it;* and yet the funeral service is read over the edge of this

mass of corruption, and priests, relatives, and friends alike are subjected to its unwholesome and dangerous effluvia. On the Sundays quite a crowd of the lower orders of the people gathers about the place attracted by the ghastly spectacle and undeterred by the evil odours of the locality, which in summer are most offensive and dangerous to health.

This system of disposing of the dead *en masse* is not confined to these cemeteries. It is carried out, perhaps not so offensively, but by similar methods, in all the cemeteries of Glasgow which sell common ground to the poor. If they do not bury in pits, they bury in indiscriminate piles. Most of them, I believe, do put a little earth over the last coffin interred, but none of them conform in any respect to the regulations which the Government has laid down in the interests of public health and decency. In the cemeteries of Edinburgh, even more insanitary and unseemly conditions existed quite recently, and the matter was investigated by the Health Authorities in 1883. On 40 or 50 common graves being probed, it was found that from 6 to 24 inches of earth covered the top coffins, and in one-third of the instances the coffins were only 6 inches below the surface. It was said that common graves were often opened and coffins transferred without any legal authority, and that the ghastly sight of a coffin which had lain in the ground for some time being carried across to a new cemetery was no uncommon spectacle. These methods of treating the bodies of the poor would not be tolerated in any other country in Europe. In view of such facts, it is no wonder that when strangers come here and see our methods, they say that we bury our poor like dogs in Scotland. Around us on every side are tracts of land saturated with masses of putridity, which will one day be surrounded, and perhaps covered, by dwellings, to which the words of Mrs. Browning may be applied with literal accuracy:—

> "The world we're come to late is swollen hard
> With perished generations and their sins;
> The civiliser's spade grinds horribly
> On dead men's bones, and cannot turn up soil
> That's otherwise than fœtid."

What has happened in the past ought to be a warning to us in the present. In 1849 burial pits were opened in vacant ground some distance behind the Glasgow Royal Infirmary. In these pits were interred, in masses, the bodies of those who died of the cholera epidemic of that year. In 1861 the new surgical department of

the Royal Infirmary was built on the edge of one of these old cholera pits. The site was praised at the time as a fine, open, healthy site. The persons who chose it had evidently forgotten about the mass of putrifying matter that lay beneath its surface. The result might have been predicted with certainty from the well-authenticated case of a Parisian hospital which had suffered from being built in a similar proximity to a graveyard. Hospital gangrene and pyæmia broke out among the patients. These diseases became so common that one of the surgeons protested against being compelled to treat his patients under these conditions, and threatened to resign unless something was done to purify the soil beneath his wards. The managers were compelled in 1867 to dig into this cholera pit, and destroy and deodorise the undecomposed remains with quick-lime and other chemical agents.

At a recent sanitary congress, Mr. Baldwin Latham, C.E., stated that, while cutting a sewer in ground adjoining the Lambeth Parish Cemetery, not far from the spot where paupers were buried in thin coffins, the work of the men was interrupted by a black putrid stream which ran from the graves. Every one of the men engaged there was afterwards taken ill from the evil effects of the putrid ichor from dead bodies exposed to rapid decomposition. On the question of water-supply, he said it was to him a matter of regret to see new cemeteries planted at places where they would affect the watersheds which gave supplies to large populations, and he could say that if the people did not suffer from this now they would in the immediate future.

Many other cases might be mentioned which would exemplify the evils, present and prospective, of such pit-burials. The reports of the Board of Health, already referred to, are full of evidence of this kind, but I think I have said enough on this department of my subject.

To sum up: By this system of pit and common-grave burial, the soil beneath and the air above become tainted with the unwholesome and poisonous products of decomposition. The sewers leading away the subsoil drainage become foul, and the streams into which these sewers empty become tainted, not only with the products of decomposition, but also with the germs of the contagious diseases. These places are not graves, but pits of putridity, and mines of profit to the shareholders. Whether they exercise it or not, the cemetery companies reserve to themselves the right to re-allocate common ground at the end of ten years. The

remains of the dead may be thrown aside, and the soil, which has been winnowed from the remains of its former occupants, may again be used for the burying of a fresh pile of coffins. There may be no end to the pollution and no end to the desecration of the graves of the poor under the present regime. Facts similar to those which I have laid before you led the Sanitary Commissioners of 1850 to the conclusion that the duty of supplying burial grounds should be taken away entirely from commercial bodies, and vested in the state. They say—"The principle of applying the spirit of commercial enterprise to this object is vicious—it is an object which can properly be effected only by a public authority devoted to the undertaking and responsible for its execution, and neither the interests nor wishes of companies, nor of any private persons, ought to be permitted to endanger or obstruct the successful result of an undertaking in the hands of an appointed and responsible authority." Again, Dr. Sutherland, in his report to these Commissioners on intramural interments, after describing the shocking condition in which he found the intramural graveyards in London, says—"The time has surely come when all trafficking in the spoils of poor humanity should cease, and when the whole process of interment should be undertaken as a solemn and pious duty, which society owes to the remains of all her members, however exalted or however humble."

My first suggestion in the direction of reform is that, as our local governors have failed to do their duty in providing cemeteries for the people, and have not placed the cemeteries within their jurisdiction under proper sanitary regulations, the Government should be approached, and asked either to insert a clause in the proposed Police Bill, placing these cemeteries under the same regulations as those issued by the Secretary of State for the government of interments in the burial grounds provided under the Burials Act; or to frame a short Act to amend the Burials Act, so as to put the private cemetery companies under these regulations.

Two fresh departures from our present methods of disposal of our dead have been suggested in recent years, which are worthy of consideration and discussion. First—A modification of our present system, either by the adoption of basket coffins, coffins of compressed cotton pulp, or shroud-burial without enclosure in any coffin. Second—Cremation and urn-burial.

In three interesting and able letters addressed to the editor of

the *Times* in 1875, Mr. Francis Haden, a London surgeon, set himself to prove that the source of all the evils alleged against burial depended upon an unreasoning sentiment which prompts us to keep our dead as long as possible and then bury them hermetically-sealed in coffins, brick graves, and vaults, so that the earth can have no access to them. He points out that this is in the highest degree unphilosophical, since it engages us in a vain resistance to an inevitable dispensation, and has led us to accumulate in our midst a vast store of human remains in every stage and condition of decay. He alleges that the process of decomposition, which, under the influence of the air is putrefaction, in the earth is resolution, and that which was offensive in the air becomes inoffensive in the earth.

Since, he says, the excreta of animals during life, and their bodies after death, must all pass through a process of decay, and in new forms re-enter the atmosphere, some provision must exist in the world by which such a vast mass of corruption as they represent may do so innocuously. That provision exists in the earth. Two distinct forms of decay are said by Mr. Haden to occur in nature—putrefaction, which is a change set up between the particles of unburied matter by the air and by water to which it is exposed, and by minute organisms which float in the air and which obtain direct access to it; and eremacausis, which is the scientific name for the effect brought about by the indirect access to the buried body of the same air and the same water winnowed of their putrescent elements by filtration, and chemically transformed by the force which is known as surface affinity. The first gives rise to compounds offensive to the senses, the last to carbonic acid, water, and ammonia, the food of plants, and, through the agency of these plants, the ultimate purifiers of the air. Our aim should therefore be, by the burial of the body, to imitate this eremacausis—to promote and not to oppose it. The new method of inhumation advocated by Mr. Haden is as follows:—

"How, then, are we to bury our dead? Clearly, within a reasonable time of their dissolution, and in coffins (if we must have coffins) of such a construction as will not prevent their resolution. No coffin at all would, of course, be best, or a coffin of the thinnest substance which would not long resist the action of the earth, or a coffin the top and sides of which admitted of removal after the body had been lowered into the grave, or a coffin of some light permeable material, such as wicker or lattice-work,

open at the top, and filled in with any fragrant herbaceous matters that happened to be most readily obtainable. A layer of ferns or mosses for a bed, a bundle of sweet herbs for a pillow, and as much as it would still contain, after the body had been gently laid in it, of any aromatic or flowing plant for a coverlet—such a covering, in short, as, while it protected the body from the immediate pressure of the earth, as effectually as the stoutest oak, would yet not prevent its resolution. I can conceive no better form of coffin. Let us emulate, too, the healthy sentiment of those older Jews who considered it an indignity and an injury to be refused prompt burial, and so made an offence to the living, and bury it while it is still grateful to every sense, and while, if we feel it an effort and a sacrifice to part with it, we may also feel that we are making that effort, and submitting to that sacrifice, in the cause of the dead."

In order to carry out these views, which were put forward in a most attractive form, a society was instituted called "The Church of England Burial Reform Association," having for its Presidents the Archbishops of Canterbury and York, and under the patronage of the leading members of the aristocracy of England. The chief reforms they advocate are economy in funerals, the disuse of crape, the early interment of the body, and the use of perishable coffins. The coffin which they now recommend is one made of compressed cotton pulp, and supplied by the Woking Cemetery Company. The honorary secretary, the Rev. Mr. Lawrence, writes—"If the dead were properly buried the evils now most justly complained of would not exist, and the requirements of right feeling and science would be satisfied. The Church's order for the burial of the dead provides such. Her use of the words 'corpse,' 'body,' 'earth to earth,' imply burial in the simplest, most speedily perishable coffin in the simple earth. This is indeed a better, because a more natural, form of cremation, called by Liebig, eremacausis, slow crèmation, the earth being in this case the crematory. The body is buried in its own grave, and there undergoes not mere decay but transformation. The earth as earth does not affect the body, but acts as the porous medium between it and the air above. Through this superincumbent earth the air descends, and resolves the body into new and harmless products, carbonic acid and ammonia, which pass upwards in air; and this process continues for three or four years, until at last the body has, in a lower and more immediate way, literally risen again and become the source of new life, leaving behind it nothing but inor-

Beth-shan, and they came to Jabesh, and burnt them there. And they took their bones, and buried them under the tamarisk tree in Jabesh." Again, in 2nd Chron. we read that the dead body of Asa was laid in a bed filled with sweet odours and divers spices, and a great burning made for him. In the same book we find that Josiah burned the bones of the priests of Baalam upon their altars. Among the prophecies of Amos, he speaks of a time when "a man's kinsman shall take him up, even he that burneth him, to bring out the bones out of the house." So the Jews burned their dead in the valley of Hinnom, in a deep ditch filled with wood and other combustibles. Isaiah refers to it in poetical language, and says, "For Tophet is ordained of old; yea, for the king it is prepared: he hath made it deep and large; the pile thereof is fire and much wood; the breath of the Lord, like a stream of brimstone, doth kindle it." From these passages it is clear that the Jews were perfectly familiar with the practice of cremation, and had no objection to dispose of their dead in this manner when they saw fit in times of war or of pestilence.

A wide-spread custom like cremation of the dead, which has continued as a common practice for ages in all parts of the world, among savage tribes and civilized nations, must have had strong grounds of utility for its continued existence. It certainly did not arise from mere philosophic or religious theories. Probably the first cause of its origin was the experience of the disagreeable and dangerous effects of the emanations from putrid dead bodies, and in well-wooded countries the ease with which, by the collection of a little fuel, the cremation and purification of the putrid mass could be effected. Another powerful incentive to cremation was the protection of the dead bodies of those who fell in battle from indignity and insult. The people of ancient times were constantly at war with their neighbours, and the victors were in the habit of inflicting the greatest indignities on the bodies of their dead enemies. We are told that the most outrageous insult that the Egyptians could inflict on their enemies was to exhume their dead and beat them with rods. It was to save the bodies of King Saul and his sons from any further insult from the Philistines that the valiant men of Jabesh stole out by night and burned their bodies. When on a warlike expedition, the bodies of their dead were thus not only protected from insult, but their ashes could be carried back to their native villages. In the same connection it is interesting to notice that the Greeks ascribed the introduction of

cremation to Hercules, who, being under the necessity of transmitting the body of Argius to his father, burned the body and sent him the ashes as the only means he could adopt to fulfil his promise.

The last general ground to which I shall refer as leading to the continuance of the custom of cremation, was the frequent occurrence of pestilences and the facts of contagion, with which the ancients were well acquainted. The terror of contagion naturally led to the burning of the bodies of those who died from contagious maladies. As civilization advanced, men came under the influence of philosophical and religious theories, many of which favoured cremation. Herodotus advocated burning of the dead in order that their bodies might more quickly return to their constituent elements. Heraclitus advocated cremation because he held that fire was the all-creating, all-sustaining principle of the universe. The followers of Odin believed that heaven of heavens was fiery, and that the soul loosened from the body by this honoured element would be most certainly and expeditiously conveyed to the seats of the blessed. They were of opinion that the honour with which the person, whose body was burned, would be received into heaven would be in the ratio of the height to which the flame of his funeral pile ascended. According to a more philosophic system of belief, by cremation "the soul, readily disengaged from its prison, purified by fire, and delivered from the burden of a perishable body, is rapidly attracted towards its own sphere, and presses on to unite itself with the soul of the universe."

The religious beliefs of the common people have a powerful influence in modifying the most deep-rooted social customs. The practice of cremation died out in Europe with the spread of Christianity. Ignorance of the chemical processes which lead to the dispersal of the material elements of our bodies in innumerable new forms of chemical combination, and their reorganization into new forms of organic life, all that is involved in the wonderful revelations of modern chemistry with regard to the circulation of matter, was to the early Christians inconceivable. They had a firm conviction that the materials of the body, although changed in form by the process of corruption, remained in the spot in which they were laid, and from thence would rise again at the resurrection. As in Egypt they embalmed the body so that it might be ready for the future state, so the early Christians buried the body that it might be ready to start up when the last trumpet should

sound. In Rome, by the end of the fourth century, the victory of Christianity over Paganism became assured, and cremation died out as a social custom. In Britain the struggle between Paganism and Christianity was more prolonged, and even when Christianity became the prevailing religion, half-converted Saxons, as has been pointed out by Professor Rolleston, would occasionally relapse into cremation. Urns found with the mark of the cross raised in bold relief show how tenaciously the old custom was adhered to. No doubt, while in a minority, the priests would tolerate this practice in deference to the opinions of their Pagan neighbours and their weaker brethren. But when the Church became powerful enough, the ancient custom was rooted out so completely that for many centuries cremation was only heard of as a means by which troublesome people, with advanced religious opinions, were speedily put to silence.

The revival of the custom of burning the dead in modern times is due to advance of sanitary knowledge and the necessities of the great city populations. The pioneers in the advocacy of the necessity for its revival have in every country been medical men. In last century a few cases of cremation are recorded. In 1769 the body of a Mrs. Pratt was, according to her wishes, expressed before her death, burned in the Tyburn burying ground in London, and in 1799 M. Voidel burned within his residence the body of his child, in order to place the ashes in a golden urn. In the early part of this century the most noted case of cremation was that of the body of the poet Shelley, which was burned in Italy in 1822 In 1869 a project for the revival of cremation was laid before the International Medical Congress held at Florence in that year. This may be said to have been the real starting-point of the modern movement; and how rapidly the movement has spread and taken practical shape may be seen by a glance at this statement in tabular form of the cremation societies and crematories which have all originated since 1874.

SOCIETIES WHICH HAVE BUILT CREMATORIES.

England, ...	London, ...	1874.
Italy, ...	Milan, ...	1876.
	Lodi, ...	1877.
	Cremona, ...	1879.
	Udine, ...	,,
	Rome, ...	,,
	Varese, ...	1880.
	Padua, ...	,,
	Brescia, ...	1882.

Germany, ...	Dresden (Gotha), ...	1876.
	Berlin, ...	——
	Hamburg, ...	——
United States, ...	Washington, ...	1876.
	Philadelphia (Lancaster), ...	——
	New York (Long Island), ...	——
Argentine Republic, ...	Uruguay, Mexico, Venezuela, Valparaiso.	

It is not possible in the time at my disposal to go into a history of this movement. Those who desire to get the best possible account of it I refer to the well-known book of Mr. Eassie on "Cremation of the Dead," and to the published transactions of the Cremation Society of England, compiled and edited by Mr. Eassie. These books are easily obtained and are most valuable and interesting reading.

I desire, however, to say a few words about the modern methods. The most approved forms of crematory are the Gorini and the Siemens. The Gorini pattern was adopted by the Cremation Society of England, and is now in operation at Woking, where 16 bodies have been cremated with the most satisfactory results. The process occupies about an hour, and the result is six or seven pounds of white ash. It is said that the entire remains of a human body only occupy a space of about 6 cubic inches. Five crematories built on the same plan exist in Italy.

A crematory of a more imposing kind was built at Gotha in Germany, after a design furnished by Mr. Frederick Siemens of Dresden. Up to the end of 1884, 200 bodies had been cremated in the Siemens crematory. It is a very perfect apparatus, but more expensive than the Gorini. The plans of these two forms of apparatus were carefully examined by an eminent Glasgow engineer, a member of this Society,* who kindly undertook to sketch a plan for a crematory which would be at once efficient and inexpensive. I show you his design, and shall read you his description of the apparatus.

If the Philosophical Society should decide to use its influence in promoting a movement in favour of the institution of a crematory in Glasgow, these plans will no doubt receive a careful consideration from those who are competent to deal with engineering questions bearing upon cremation. I have already indicated my reasons for holding the opinion that cremation is the only scientific

* Mr. Stephen Alley, of the Sentinel Engineering Works.

and satisfactory method by which we can at once get rid of the evils of putrefaction, and destroy germs of dangerous contagious maladies; and the short account which I have given you of the origin and widespread practice of the custom shows that it is a process which naturally commends itself to the human mind if that mind is not prejudiced by erroneous opinions.

I shall now confine myself to a short consideration of the objections which have been urged against the practice. Since the trial of an eccentric Welsh surgeon for the burning of the dead body of his child in 1874, the objection that the practice of cremation is illegal has not again been raised. In his charge to the jury on that occasion, Mr. Justice Stephen discussed the whole legal bearings of the question, and in the course of his remarks he said:—"The great leading rule of criminal law is that nothing is a crime unless it is plainly forbidden by law. I think that to burn a body decently and inoffensively is lawful, or at the very least is not criminal. If it is done in such a manner as to be offensive to others it is a nuisance. To burn a body in such a place, or in such a manner, as to annoy persons passing along public roads or other places where they have a right to go is beyond all doubt a nuisance." On this ruling Mr. Price was acquitted, and since that time the Cremation Society of England, as already mentioned, have cremated 16 bodies in the crematory at Woking. The legal objection which was stated a few years ago has, therefore, been removed.

A variety of sentimental and theological objections which were strongly urged a few years ago are fast disappearing. The one objection which is still strongly urged by the opponents of cremation is that its general adoption would facilitate secret poisoning. There is certainly a danger in this direction if cremation is not guarded by some regulations under the authority of an Act of Parliament of the nature contemplated by Dr. Cameron in his Disposal of the Dead Regulation Bill. This Bill was drafted for the purpose of affording some additional guarantee for the detection of foul play before ordinary burial or cremation; but it was specially intended to remove an objection to cremation, and was most ably advocated, not only by Dr. Cameron, but also by such men as Dr. Farquharson and Sir Lyon Playfair. Sir Lyon Playfair is reported to have stated in his speech on that occasion that "secret poisonings were of two kinds, one by metallic and one by organic poison. Both cremation

and burial were" he said "equal in their effects on organic poisons (*i.e.* they disappeared so that no trace was left in the body which could be detected by chemical analysis), but metallic poison would generally be left in the ashes, with the exception of arsenic. The benefit to the living would," in his opinion, "be so great under cremation, as compared with the present method of disposal of the dead, that any occasional miscarriage of justice would be but as a drop in the ocean." As a distinguished chemist, Sir Lyon Playfair's opinion is worthy of attention. Dealing with the same point, Dr. Farquharson said, "Much had been made of possible medico-legal difficulties, and it must be allowed that a very slight and infrequent source of danger might thus arise, totally insufficient, however, to counterbalance the benefits derived by the community at large by the more speedy disposal of the dead. As Sir Henry Thompson pointed out, in doubtful cases portions of the stomach and liver might be preserved for future analysis, and of course many metallic poisons could be readily detected in the ash."

Then Dr. Cameron said, "So far as the destruction of evidences of poisoning is concerned, the difference between cremation and inhumation is simply one of degree. As to mineral poisons, direct experiments instituted by M. Cadet, and repeated by MM. Dourvault and Wurst, have proved that the salts of arsenic and all other metallic poisons, except mercury, which is completely volatilised, can be detected in the ashes after cremation. As to organic poisons, most, if not all of them, are destroyed by putrefaction, though of course more slowly than by fire. But what is wanted to ensure their detection is prompt verification of the cause of death, and the system which I propose would afford an infinitely better chance of that than anything contained in our present burial laws. As to the poor and ignorant poisoner, the regulation of cremation, as I suggest, would afford an infinitely better chance of his detection than its prohibition; and as to the rich and skilful criminal, it is childish to think of baffling him by prohibiting cremation, so long as you permit him to remove the viscera of his victim, and preserve him by the aid of arsenic and corrosive sublimate under pretence of embalming his remains. It is childish to think that any law can place an effective obstacle in his path, so long as you permit him to transport the body of his victim to foreign countries, in order that he may there bury or burn him altogether uncontrolled by your laws." On reading these

statements, there seemed to me great improbability in the assertion that the salts of arsenic, and of all other metallic poisons except mercury, would remain after exposure to a temperature ranging from 1,400 to 2,000 degrees F. We know that arsenic vaporizes at 370 F., mercury at 660 F., antimony and zinc at a bright red heat, and lead at a white heat. So that we would expect that these metallic poisons would disappear in the process of cremation. The salts of these metals are usually reduced to the metallic state when heated to the proper point in contact with charcoal, we would therefore expect them to behave like the metals themselves when subjected to the heat of the crematory furnace in a human body. In order to put this to the test, I performed some experiments—First, I cremated in an asbestos box the dead body of a cat, weighing 7 pounds, in the furnace of an engineering works, which was used for softening brass plates. The temperature was estimated at about 1,400 F. Before cremation, I injected into the abdomen of this dead cat a mixture of 5 grains of arsenious acid with 5 grains of corrosive sublimate in a little water, and into its pleural cavity 5 grains of tartrate of antimony. I show you the remains of the asbestos box, which began to crack in a few minutes after its introduction, and in ¾ of an hour, when the cremation of the cat was completed, it was reduced to the ruin which you see. I sent the ashes of the cat, which were so mixed with the debris of the asbestos that I did not attempt to separate them, to my friend Dr. Milne, lecturer on chemistry in the Royal Infirmary School of Medicine, who, after careful search by the usual chemical tests, failed to detect any trace either of the arsenic, of the corrosive sublimate, or of the antimony. I next cremated the dead body of a dog weighing 20 pounds. Into the abdomen of this dog I injected a mixture of 40 grains of subacetate of copper, and into its pleural cavity a similar amount of acetate of lead. It was placed in an earthenware vessel and exposed for 12 hours to the heat of a pottery kiln, estimated by the manager at about 1,800° F. After this exposure, the bones still retained their shape, but were so brittle that they could be pulverised with the fingers. Some of the bones were found on removal from the kiln to be deeply stained by the copper. The bones and ash were subjected to analysis by Dr. Milne, who discovered abundant evidence of the presence of both copper and lead. I was informed that in forming alloys of copper, antimony was sometimes used as one of the alloys, and that although subjected to a temperature of 2,000° F., which is about the melting

point of copper, it did not, under these circumstances, sublime. I therefore tested the behaviour of a mixture of arseniate of copper mixed with tartrate of antimony, under the conditions of cremation. I injected into the abdomen of a dead rat weighing 5½ ounces a mixture of 5 grains of each of these substances, and cremated it in an earthenware plate in a domestic stove. The stove was heated to a bright red heat, and in 20 minutes the rat was completely cremated. The ashes weighed ¼ of an ounce. On testing these ashes Dr. Milne could find no trace of the arsenic but abundant traces of antimony with the copper deposited on the bones. It is apparent from these experiments that arsenious acid, corrosive sublimate, and tartrate of antimony, the three most common, and therefore most important mineral poisons, disappear from a body under the conditions of cremation, and are not to be detected in the ashes. But in the presence of copper antimony and lead remain, while even in the presence of copper arsenic disappears.

Although from the result of these experiments, and from a consideration of the well-known chemical properties of poisons, I am quite prepared to admit that all the most important and commonly used poisons disappear and leave no trace in the cremated ashes, I hold with Dr. Cameron and the supporters of his Bill, that means can be adopted which will make the community safer from secret poisoning under cremation than it is at present under inhumation of its dead. The only other objection which I shall refer to on this occasion is that urged by such men as Professor Rolleston, antiquarians, anatomists, and pathologists. They object that cremation would destroy interesting pathological specimens, and so would prevent our remote descendants from knowing what kind of people their predecessors were.

It is quite sufficient answer to this objection that even when cremation is anxiously desired, as by the poor Hindoos, a large proportion of the dead are inhumed for economic reasons. The Hindoos can bury for two rupees, and they cannot burn for less than double that amount. Cremation can only be carried out cheaply on the large scale in our great cities. There will, therefore, be plenty of material left for our remote descendants.

In conclusion, I would suggest that in order to carry out the reforms on our present methods of burial, which I have sketched out roughly and imperfectly in this paper, a society should be started in Glasgow to be called "The Scottish Burial Reform Association." That this society should have four very definite

objects: First—To call upon the local authorities at once to remove from among us the scandal of pit-burials, which leads strangers who come to Glasgow and see our methods of interment to say that we bury our poor like dogs in Scotland. Second—To seek the necessary legislative amendment of the Burials Act, which will place private cemetery companies under its regulations. Third—To advocate economy in funerals, and the adoption of perishable coffins. Fourth—To secure the erection of crematories in our large cities, and their proper regulation.

If you, gentlemen, are satisfied that the facts which I have stated warrant an active movement in favour of reform, I would suggest that this whole question of burial reform should be remitted to the Council of the Sanitary and Social Economy Section for consideration, with powers to take such action on behalf of the Society as the Council may deem advisable in the social and sanitary interests of the community.

PROPOSED CREMATING FURNACE.

PLATE VI.

Fig. 1.—Longitudinal section through furnace.

Fig. 2.—Cross section of furnace, showing the crematory tray placed in the furnace, the outer door of furnace being closed down.

Fig. 3.—Cross section of furnace, showing crematory tray being placed in position or removed by means of a carriage provided with prongs that are free to pass under the crematory tray at four places, G, G, G, G.

The furnace is of the same class as is used for heating iron for forging purposes. The fire (A) is at one end, and the products of combustion are principally consumed in the body of the furnace (B), where the crematory tray (C) is placed; the waste gases are carried away through the throat (D), and may, if desired, be passed through a clear fire (E) before being carried off by the chimney (F).

The body to be cremated is placed in the tray (C) on the projecting prongs (J) of the car (K), when it is at some distance from the furnace mouth. The weight of the tray and body is balanced by the back balance weight (L) fixed to the bottom of the car. After the last ceremony, the furnace door (H) is lifted, the cremating tray run in, and the projecting prongs are lowered by means of the hand wheel on the end of the carriage, which is then drawn back, the door of the furnace lowered, and the body to be cremated left in the tray in the position shown in Fig. 2. It is proposed to make the crematory tray of fire-clay of the same quality as is used for gas retorts. After cremation the tray is withdrawn containing the ashes, which can be collected.

Such a furnace, if made without any ornamental facings, should be constructed for about £150 to £160, including the carriage. When once heated the cost of maintaining the heat will be about 6s. per hour.

XXII.—*The late* ROBERT GRAY, *V.P.*, R.S.E., Corresponding Member. By J. B. MURDOCH, F.R.Ph.S.E.

[Communicated to the Society, 4th May, 1887.]

WHEN we take into consideration the innate love for animated nature in all its attractive forms which is common to humanity, it is a matter for wonder that so few men, comparatively, take up the systematic study of any of the branches of natural history, and that there are still fewer who attain anything like eminence in their investigations. Of those who have devoted their attention to Scottish ornithology our late respected corresponding member, Robert Gray, had, many years ago, reached the front rank, and I think it is therefore only right that a short memorial notice of him should be brought before the members of the Philosophical Society. As a boy he was passionately fond of living creatures, particularly birds—a love which time only served to deepen; and, perhaps, to this early fondness may be traced his great enthusiasm for bird-life whenever and wherever he came in contact with it.

Robert Gray was born at Dunbar on the 15th of August, 1825, having thus at the time of his death reached his sixty-second year. On leaving school he entered the service of the City of Glasgow Bank under the agent in his native town, and remained there till about the age of twenty, when he was promoted to a post in the headquarters of the bank at Glasgow. Here he gained the respect and goodwill of his superiors, quickly passing through the various grades of work until he received the appointment of inspector of branches, and, latterly, the managership of the bank's West-end Branch. About the year 1874 he was offered and accepted the post of inspector of branches in the Bank of Scotland, which involved his removal from Glasgow to Edinburgh. In 1882 the directors appointed him cashier, and this responsible position he occupied at the time of his death, on the 18th of February last.

When I first made his acquaintance, in 1851, Robert Gray was one of the tellers in the Head Office of the City of Glasgow Bank, in Miller Street, his next neighbour and co-teller being William

Sinclair, an admirable sketcher of bird-life, who afterwards drew the illustrations for the "Birds of the West of Scotland." At that time all his spare hours were given to natural history, for, although ornithology came first, botany and conchology interested him deeply. Even geology was not forgotten, as we shall see, although it was not until a much later period of his life that he devoted special attention to its study.

There being at that time in Glasgow no society devoted to the study of the natural sciences, Mr. Gray called a meeting of a few friends interested in it on the 2nd of July, 1851. This gathering resulted in the formation of the Natural History Society of Glasgow, Robert Gray being chosen secretary; and this post he continued to hold till 1871, when increasing official duties compelled his resignation. It cannot be gainsaid that under his management this society became a powerful agent in promoting the pursuit of ornithology in the West of Scotland, a position which for years after his retiral it continued to hold.

It may be interesting to note here the names of the gentlemen —nine in number—who attended this preliminary meeting, several having been active members of the Philosophical Society, while all, with only two exceptions, have now passed over to the majority. They were—Dr. W. B. Lorrain, William Gourlay, Thomas Gray (alive), William Ferguson (of Kinmundy, alive), James P. Fraser, Robert Gray, John Gray, Thomas Ferguson, and Archibald Gray. About a week later Dr. Hugh Colquhoun and William Keddie were enrolled; while very shortly afterwards Sir (then Mr.) Michael Connal and the present writer became members.

During the whole period of Robert Gray's secretaryship, which extended to twenty years, the minutes of meetings of the Natural History Society bear evidence of the great amount of material which he laid before the meetings, many of the subjects involving very considerable investigation and research. One of the most noteworthy of these was an exhaustive paper on "The Birds of Ayrshire and Wigtownshire," a number of the observations recorded in it being made by his father-in-law, Mr. Thomas Anderson, of Girvan. In its concluding sentences the author strongly urged the necessity of some legal protection for land-birds, the law having already recognised the fact that sea-fowl were not to be driven out of existence by thoughtless shooters; and he urged *it not on mere* sentimental grounds, but on economic ones, holding

strongly, as he did, that almost all birds were much more useful to the farmer than they were harmful. I am happy to say that Mr. Gray's views on this subject became generally accepted, and that a few years ago a close time for all birds—from 1st March to 1st August—was enacted by Parliament. This modified protection is now undoubtedly benefiting the feathered tribes, without, so far as I can learn, injuring agriculturists. In connection with this subject it may be stated that, consequent upon various visits he paid to Ailsa Craig for the purpose of studying the habits of its bird population, Mr. Gray publicly expressed strong views as to the impolicy and cruelty of the indiscriminate slaughter of the sea-fowl which, and more especially at their breeding time, the lessee of the rock engaged in. A correspondence in the *Times* with the Marquis of Ailsa ensued, the primary result being that Mr. Gray was forbidden to set foot again upon the "Craig"—a prohibition which was never removed, at least he told me so in 1885. The public remonstrances had, however, some effect, and I believe that the practices complained of were departed from, or at least relaxed.

As was naturally to be expected, all this accumulation of facts and figures regarding birds and bird-life became too valuable, and of too much interest to a wide circle of naturalists, to be left in an undigested state, and, consequently, in 1871 appeared the well-known, and highly esteemed, "Birds of the West of Scotland," a handsome octavo volume, which, originally issued to subscribers at 7s. 6d., has become so "scarce," in booksellers' parlance, as to command from 40s. to 50s. per copy. I need hardly add that since its publication it has been the accepted text-book of Scottish ornithology.

Robert Gray was a delightful correspondent, and his letters were brimming with interest, while, as in his papers, touches of a pawkie humour were constantly to be met with. The range of his correspondence was very wide, for in the days of his inspectorship of branch banks he had become acquainted with, generally speaking, every bird observer in the country. To this circumstance must be attributed much of the wealth of material embodied in his book just spoken of, for no sooner was a rare or unknown bird seen or procured anywhere than he was sure to hear of it, and, most probably, to acquire it.

On leaving Glasgow to take up his residence in Edinburgh, Mr. Gray, as a mark of respect, was elected a corresponding member

of this Society, and also an honorary member of the Natural History Society, and he speedily became a fellow of the Royal Society of Edinburgh, and the Royal Physical Society of Edinburgh. The latter had almost fallen into a moribund state, but our friend became its secretary, and his efforts to revive its drooping energies were crowned with such a measure of success, that in a comparatively short time it began a renewed state of existence, assuming that condition of activity and prosperity which it still enjoys. Much of the ornithological work which used to find an outlet in Glasgow has, during the last few years, been diverted to the meetings and *Transactions* of the Royal Physical Society. Of the Royal Society, Mr. Gray was, for several years before his death, a vice-president, a distinction to which his attainments, as well as his unfailing tact and *bonhomie*, eminently entitled him. The last session of the society he closed with an appropriate address, and up to almost the last few meetings there was hardly one that did not see his genial and welcome presence.

During the last seven or eight years of Robert Gray's life in Edinburgh he had been preparing, in conjunction with Mr. William Evans, of the Scottish Widows' Fund, for the publication of a work upon "The Birds of the Basin of the Forth." As the materials grew so did the scope of the volume, and his latest intention was to make it embrace the East of Scotland generally. I am glad to learn that the data were practically completed before his death, and that Mr. Evans intends to finish and publish the joint work.

Mr. Thomas Anderson, of Girvan, his father-in-law, besides being a bird observer, had long been a collector of the Silurian fossils of his neighbourhood, and his daughter doubtless inherited similar tastes. For a number of years past Mr. and Mrs. Gray and their family were in the habit of spending the summer vacation in or near Girvan, and they devoted themselves to working out the palæontology of the district. This resulted in the formation of such an important collection that the Royal Society of London made a grant of money to defray a portion of the cost of its description and illustration. The work was taken in hand for a time by Professor Alleyne Nicholson, of Aberdeen, and Mr. Robert Etheridge, jun., of the British Museum, three large and handsomely-illustrated parts being issued. The authors have, however, been unable, from want of time, to proceed further, and the publication remains at present in an unfinished condition, though

it is to be hoped, for the sake of science, that the numerous undescribed forms the Gray collection contains will ere long find a competent describer and illustrator.

Notwithstanding his busy official life and his scientific pursuits, Mr. Gray found time to take an active part in the relief of distressed and unbefriended genius, and many a case might be quoted to show his generous and unselfish assistance.

Take him all in all, he was an active, kindly, high-souled worker, such an one whose removal from amongst us makes every one the poorer—a man with many friends and no enemies.

Mr. Gray is survived by a widow, two sons, and two daughters, most, if not all, of whom inherit his artistic and scientific tastes. May I suggest that a vote of condolence with Mrs. Gray and her family might be passed by the Society, and an extract from the minutes forwarded to her by the secretary?

XXIII.—*On the Reducing Action of Hydrogen in presence of Platinum.* By STEPHEN COOKE, F.C.S.

[Read before the Society, 4th May, 1887.]

SEVERAL years ago I made some experiments on the action of hydrogen on solutions likely to be reduced by this gas. With hydrogen alone, however, in most cases no action was observed. It then occurred to me that the action might be promoted by the presence of finely divided platinum; for although the action of this substance is so well known in bringing about the combination of gases with each other, it has not, as far as I am aware, been much used to bring about or accelerate the action between gases and liquids. Gladstone and Tribe (*Journ. Chem. Soc.*, xxxiii. 306, 1878) have shown that hydrogen occluded by finely divided metals is analogous to nascent hydrogen. The same conclusion may be drawn from the results of my own experiments, which were, however, made in a somewhat different manner, and were rather more extended than those of the above-mentioned chemists.

Most of my experiments were made in tubes closed at one end, and from 300 to 400 mm. in length, and about 15 mm. in diameter. A piece of platinum foil as long as the tube, and of such a width as to pass freely into it, is placed in the tube, and kept in its place by a wire passing through the closed end, and projecting a few millimetres from it. The foil can be coated with platinum black by electrolysis, and the coating can be readily renewed, without removing the foil, by filling the tube with platinic chloride, and connecting the wire passing through the sealed end with the zinc end of a battery, the other pole being a wire passing through a bit of small glass tube and projecting a little from the closed end.

Platinum foil so prepared gradually loses its activity or power *in bringing* about combination. Between hydrogen and liquids this

loss of activity for the most part merely results in a slower action, the *nature* of the change being the same. In the case of some gases, however, not only is the rate but also the kind of the chemical change to some extent influenced by the activity of the platinum; but this may be due to the higher temperature produced, and not to any increased activity of the occluded hydrogen.

The efficiency of the prepared platinum can be readily tested by transferring electrolytic gases to the tube. Perhaps one or two experiments may not be out of place. A freshly-prepared tube was rapidly filled with a mixture of electrolytic gases; there was a rapid contraction for five or six seconds, followed by an explosion. In a similar tube which had been in use some months, the contraction was much slower, taking from 10 to 15 minutes, and there was no explosion. In a tube containing foil which had not been coated or specially cleaned, the gases took about thirty hours to disappear.

The hydrogen was in most cases made by the electrolysis of pure dilute sulphuric acid, but in some cases by dilute sulphuric acid and zinc.

The experiments were generally made by filling the tube with the solution under trial, then displacing the solution with hydrogen, and leaving the filled tube standing in the solution. With corrosive liquids, instead of the tubes just described, a V tube may be used, one limb of which is closed, and contains the prepared foil.

Nitric Acid.

A number of experiments have been made on the reducing action of occluded hydrogen on nitric acid and other oxygen compounds of nitrogen, and as the action of this gas can be studied on each compound apart from the rest, and as hydrogen in this condition resembles in its action nascent hydrogen, the results may reasonably be expected to throw a little light on the difficult and complicated subject of the action of metals on nitric acid.

A tube of electrolytic hydrogen was kept over nitric acid (sp. gr., 1·42) for six weeks; there was not, however, the least sign of any absorption. Similar tubes were kept for several months over acid somewhat more diluted than this, but no contraction of the volume of gas was noted in any case. This, then, shows the remarkable difference between ordinary or molecular hydrogen

and the same element in a nascent state—a difference generally attributed to different atomic aggregation.

Hydrogen in contact with prepared platinum foil acts very readily on nitric acid. With acid of sp. gr., 1·42, red fumes make their appearance almost immediately and attain their maximum in a few minutes; there is then a gradual contraction in the gas, which is not quite absorbed for an hour or two unless the tube be agitated. The acid has by this means acquired a yellow appearance, being evidently reduced to nitrous acid.

With acid more diluted than this, the results are similar, but the fumes are less red, and with an acid weaker still, no red fumes appear; the action, therefore, is between the hydrogen and vapour of nitric acid.

If the acid (1·42) be diluted with four or five times its volume of water, it is still acted on by hydrogen pretty rapidly, the contraction being from 40 to 50 mm. per hour, depending on the freshness of the platinum black; the resulting acid has a nitrous smell and a reducing action on potassium permanganate. More diluted still, the action is slower, but still there is an action, the lower limit of which I did not determine. With normal acid, however, the action is exceedingly slow; in seven days the contraction was only 30 mm. in one of my experiments; with one-half normal (the weakest acid used in this mode of experimenting) the action was much the same.

Heat will greatly accelerate the action of hydrogen on dilute acid. For this purpose the tube is filled to the extent of about three-fourths with hydrogen, and either sealed up or closed with a good cork; it must be tied, and then placed in a slanting position, so as to expose as much foil as possible to the liquid and gas in the water bath.

Heated in this way with normal acid, the absorption was almost complete in two hours, the acid in the tube giving the reaction for nitrous acid, and also indicating a little ammonia with Nessler's reagent.

With half normal acid treated in the same way the result was pretty much the same; less nitrous acid and more ammonia appeared to be produced. With one-eighth normal acid the action was slower, but by six hours' heating in the water bath nearly all the hydrogen had disappeared.

With $\frac{1}{16}$, $\frac{1}{32}$, and $\frac{1}{64}$ normal acid the action was very similar; in from five to eight hours the hydrogen almost or quite disappeared,

and the residue in the tube gave in every instance the reactions of nitrous acid and ammonia. No acid more dilute than $\frac{1}{64}$ normal was experimented with.

The action of occluded hydrogen on these dilute solutions of nitric acid is interesting, as showing the activity of hydrogen in this condition; and for the purpose of comparison I have sometimes made an electrolysis of acid of the same strength, using a very weak current. Some of the hydrogen under these conditions will reduce a portion of the acid, but another part of the hydrogen always appears in a free state at the negative pole, showing that the gas in this condition can with difficulty, and only incompletely, reduce acid so dilute, which acid is freely acted on by occluded hydrogen if assisted by a moderate heat.

Nitrates.

The nitrates are all reduced by occluded hydrogen, but the action is not quite so rapid as with some other solutions. Hydrogen standing over a saturated solution of potassium nitrate was absorbed to the extent of 25 c.c. in six days; the solution in the tube smelt of ammonia, and showed that a nitrite had been formed. With sodium nitrate the action was very similar. Hydrogen sealed up in a tube containing platinum, with a strong solution of potassium nitrate, acted much more rapidly on exposing it to the heat of the water bath. The gas had almost disappeared in two and a half hours, and the solution had a strong smell of ammonia, and gave a reaction for a nitrite.

Hydrogen standing in a similar tube without platinum over a concentrated solution of nitre, gave no contraction in one month; and a similar sealed tube exposed to the heat of 100°C. in a water bath for some hours showed no signs of contraction.

Crumpled platinum foil, coated with platinum black, was placed in a flask and half covered with a solution of KNO_3; when the flask was filled with hydrogen and heated on a water bath, the solution showed in a few minutes an alkaline reaction, and there was an evolution of ammonia. Other nitrates are also reduced. Those of barium and calcium, for instance, are reduced gradually at ordinary temperatures, and much more rapidly at the temperature of boiling water.

Cobalt Nitrate.—Hydrogen (without platinum) stood over a strong solution of cobalt nitrate for some weeks; but there were no signs of absorption. In the presence of coated platinum, however,

there was a gradual but slow contraction of the gas. In a week this amounted to a column 150 mm. in height; on the foil there were a few spots of a greenish-blue colour, and a brownish-yellow flocculent matter deposited. Some of the same solution was sealed up in a tube with hydrogen, and heated for one hour (in presence of platinum); at the end of that time all the hydrogen had disappeared.

Nickel Nitrate.—This compound behaves in a similar manner, being slowly acted on at ordinary temperatures, and by two hours' heating in the water bath the action is complete. No action occurs without the platinum.

Lead Nitrate.—When treated in the same manner, this body gave similar results; without the presence of platinum it gave no result, either hot or at ordinary temperatures.

Copper Nitrate.—Russell (*Journ. Chem. Soc.*, xxvii. 3, 1874) states that copper nitrate and some other substances appear to be reduced by hydrogen; no particulars of experiments are, however, recorded. I have kept hydrogen standing over a strong solution of this salt for some weeks without any obvious result; in the presence of platinum, however, the hydrogen is readily absorbed, with a production of copper nitrite, apparently. (In one of my experiments a slight deposit of metallic copper seemed to be formed on the platinum foil, but this is not always the case.) *Nitrates of mercury* and *bismuth* are acted on by occluded hydrogen.

Silver Nitrate.—Chemists are by no means unanimous as to the action of hydrogen on silver nitrate. A diluted solution of this salt is readily reduced by occluded hydrogen to a metallic state, small brilliant-looking crystals making their appearance on the foil. The action with platinum was about ten times as rapid as without, with a dilute solution; with a concentrated one, the difference is not so marked. I did not see any reduction to nitrite, mentioned by Russell in the paper above alluded to, but the reduction did not, I expect, go far enough to produce this salt.

From these experiments it appears that all nitrates are readily reduced by occluded hydrogen.

Chlorine, Bromine, and Iodine.

Chlorine in the dark does not, as is well known, combine with hydrogen. I kept a tube of hydrogen standing over chlorine water for seven days, but there was not the slightest contraction. In the presence of platinum, however, the contraction is at the rate of 50 or 60 mm. per hour; but with chlorine and bromine the

finely divided platinum is liable to become detached from the foil, and hence the action after a time becomes slower.

Hypochlorous acid is reduced by hydrogen under the usual conditions of experiment.

Hydrogen standing over a saturated solution of $KClO_3$ showed no contraction in six weeks. In the presence of the prepared foil the action is fairly rapid, being at the rate of 10 mm. per hour. The chlorate is reduced to chloride; a quantitative experiment accounted for all the hydrogen absorbed.

Potassium perchlorate is not acted on.

Bromine water acts pretty much the same as chlorine. Iodine in a solution of potassium iodide is acted on more slowly.

Bromates and iodates were not experimented with.

Concentrated Sulphuric Acid.

It is sometimes stated in text-books that hydrogen attacks concentrated sulphuric acid; *e.g.*, in Frankland's and Jaap's Inorganic Chemistry the following note occurs:—"The use of concentrated sulphuric acid, as a desiccating agent, ought to be avoided, if a very pure gas (hydrogen) is required, as hydrogen slowly reduces this acid in the cold, with formation of sulphurous anhydride." In order to test this, I kept pure hydrogen over pure concentrated sulphuric acid for three weeks. There was no sign of contraction, and the acid had no smell of SO_2, and not the least reducing action on potassium permanganate. The reducing action of hydrogen on this acid must therefore be extremely small to exhibit no action in three weeks, and I cannot help thinking that one might safely dry hydrogen by means of sulphuric acid, provided the gas be pure; should it contain sulphuretted or phosphoretted hydrogen it would be quite another matter.

In contact with prepared foil the action is very different. There is a steady but slow absorption, which amounted to 150 mm. in three days. The acid when examined smelt strongly of SO_2, and had a reducing action on potassium permanganate.

Hydrogen reduces H_2SO_3, but the action is slow.

Permanganates.

Potassium permanganate is slowly reduced by hydrogen, but the action is very slow; in the presence of platinum it is much hastened; but even in this case it is slower than one would have

expected, the upper surface of the foil soon becoming exhausted unless agitated.

Bichromates.

An acidulated solution of potassic bichromate was not reduced by hydrogen in six weeks without platinum; with platinum, the action is steady and fairly rapid.

Ferric Salts.

Ferric salts are not reduced by prolonged contact with hydrogen. In presence of platinum ferric chloride is readily reduced, and the reduction proceeds with great regularity; if the platinum deposit be fresh, the contraction will amount to 50 or 60 mm. per hour. The greater regularity shown in the reduction of this salt, compared with some others, is owing no doubt to its solubility, thus preventing the upper layer from becoming exhausted.

Ferric sulphate is very readily reduced by hydrogen in presence of platinum. In my experiment the action seemed a little more rapid than with the chloride.

Warren, in a recent number of the *Chemical News*, has suggested the use of ferric salts instead of potassium bichromate as a fluid for the galvanic battery. I know nothing of its efficiency for that purpose, but in my experiments a concentrated solution was more readily reduced than the acidified bichromate.

Mercuric Salts.

Mercuric chloride was not reduced by hydrogen alone in six months. With platinum it rose 75 mm. in twelve hours, and a crust of white powder (Hg_2Cl_2) coated the foil. After a time the action became much slower from exhaustion of the upper layer.

Platinum Salts.

Platinum chloride is slowly reduced by hydrogen alone in the cold. The presence of the prepared foil greatly accelerates the action, which is as great in one hour with the foil as in 48 hours without it. The upper layer is completely reduced, becoming quite colourless.

Ferricyanides.

Hydrogen standing over potassium ferricyanide was reduced by 15 mm. in twelve months; with the foil it is pretty readily reduced to ferrocyanide.

Action of Hydrogen on Nitric Oxide in presence of Platinum.

Although this paper deals chiefly with the reducing action of hydrogen, it may not be out of place to mention here a few experiments with nitric oxide and hydrogen. The subject is by no means a new one. Most chemical works record the fact that hydrogen and nitric oxide give rise to ammonia when led over gently-warmed spongy platinum, and the reducing action of nascent hydrogen on the same gas is employed in preparing hydroxylamine. The method I have adopted in studying the reducing action of hydrogen seemed suited also to investigate the action of gases on each other, inasmuch as the residual gases can be readily measured and examined. I have made a great number of experiments with these gases, and some of the results seem worth recording.

The experiments were, for the most part, made in the same tubes I have already described, some experiments on a much larger scale. In some cases the experiments were made over mercury, generally over water. One volume of hydrogen and two volumes of nitric oxide standing over mercury gave a very regular action, and the results of the different experiments were constant and represented by the equation $2\,NO + H_2 = N_2O + H_2O$. (Although standing over mercury the gases were moist, as the tube was first filled with water, over which the mixed gases were collected. If the tube had been filled with mercury the finely-divided platinum would have amalgamated with the mercury and so lost its activity.) Equal volumes of nitric oxide and hydrogen, treated in the same way, gave a contraction equal to one-half the original volume, the residue being nitrogen.

Made over water, the results are pretty much the same; on the whole, they are, perhaps, a little less regular, due, no doubt, to the solution of a little of the nitrous oxide in the water.

With a larger proportion of hydrogen the action is much more rapid, taking place in the course of a few minutes if the platinum is pretty active, and leaving a strongly alkaline residue. Similar experiments made on a larger scale gave very interesting results.

Hydrogen, to the extent of 600 c.c., was collected in a cylinder, in the upper part of which a large piece of platinum foil was placed; 150 c.c. of nitric acid were added rapidly. There was an almost immediate action—first the water in the cylinder was some-

what depressed, and heavy whitish fumes appeared near the foil; there was then a pretty rapid contraction of the gas till only 300 c.c. remained, 450 c.c. having disappeared. This action only took a few minutes, and considerable heat was developed during the change. The residue was chiefly hydrogen, but it contained a little nitrogen; all the nitric oxide had disappeared, and there was no nitrous oxide in the residue. The liquid was strongly alkaline, and gave the reaction for hydroxylamine.

Similar experiments have been made with like results, and the contraction is very often the same as the above, though sometimes it may be a little less.

Ammonia is formed at the same time, and the change might be represented as follows:—

$$2\,NO + 8\,H = NH_3O + NH_4HO.$$

This, however, does not account for the small amount of nitrogen resulting from the experiment. This is a very interesting reaction, but by no means an unexpected one, seeing that hydroxylamine is prepared by the action of nascent hydrogen on nitric oxide.

If the nitric oxide is added in a much smaller proportion than was used in the last-mentioned experiment (viz., 1 to 4 hydrogen), the action appears pretty much the same, but much slower: for instance, I added to 600 c.c. of hydrogen 50 c.c. of NO, and the action was not complete for one hour, when 150 c.c. had been absorbed; on adding another 50 c.c. a similar contraction takes place. After a time, however, the contraction is less than that just indicated.

These experiments show the influence of mass in determining chemical change. With a small amount of hydrogen the reduction is to nitrogen and nitrous oxide; when the hydrogen is greater in amount, ammonia and hydroxylamine are the chief products of the reaction.

As in these experiments the nature of the change depends largely on the mass of gases present, I tried the effect of the copper-zinc couple on nitric oxide, by placing a piece of zinc in a tube, coating it with copper, and then filling the tube with nitric oxide. The action is not very rapid, and the gas left is from one-fourth to one-third of the nitric oxide taken; ammonia and a little hydroxylamine are formed.

In this case, therefore, the hydrogen is to some extent capable

of uniting with the nitrogen, but not nearly to the extent that it does when there is a large mass of hydrogen in presence of platinum.

In presence of platinum, nitric oxide is reduced by carbonic oxide, forming nitrous oxide or nitrogen according to the quantity of CO present.

Nitric oxide is also reduced by ammonia in presence of platinum. Nitrous oxide is reduced by hydrogen, ammonia, and carbonic oxide in presence of platinum.

In a few experiments, when nitric oxide was mixed with the smaller proportions of hydrogen mentioned, there were slight indications of hyponitrous acid; in other cases, however, no trace of this body could be obtained. If this substance is formed, I believe its formation depends on the activity of the platinum.

These experiments may be considered as proving that hydrogen in presence of finely divided platinum possesses all the properties of nascent hydrogen. In many cases the action is slow, but in some it might perhaps be used as a means of reduction when the presence of sodium-amalgam or the copper-zinc couple is objectionable.

XXIV.—*Note on the Action of Electric Sparks on Mixtures of Nitric Oxide with Hydrogen and other Inflammable Gases.*

By Stephen Cooke, F.C.S.

[Read before the Society, 4th May, 1887.]

Davy, in his Researches on Nitrous Oxide, says:—"I passed a strong electric shock through equal parts of hydrogen and nitrous gas, confined by mercury in a detonating tube, but no inflammation and no perceptible diminution was produced." This statement, which I believe is quite correct, is still found in some of our works on Chemistry (*e.g.*, Gmelin's). And nothing is said about the action of sparks on these gases mixed in other proportions, although Davy, a little further on, says:—"Perhaps if I had tried many other different proportions of the gases, I should at last have discovered one in which they would have inflamed; for, as will be seen hereafter, nitrous oxide cannot be decomposed by the compound combustible gases, except definite quantities are employed." This paragraph to a great extent anticipates my experiments on this subject.

Henry, however, is less cautious, and in his *Elements of Chemistry (9th ed.)*, he makes the following statements (on what authority I do not know, but he seems to have experimented on the subject himself):—"It [nitric oxide] does not, however, explode with hydrogen *in any proportion, nor with any of the varieties of carburetted hydrogen.*" (The italics are mine.) And, again, "Nitrous gas does not with hydrogen gas afford a mixture that can be exploded by the electric spark." Henry's statements, as I shall show immediately, now need modification.

My own experience on this subject may not be uninteresting. The first mixture used was equal volumes of nitric oxide and hydrogen, this being the most likely proportion to give any result. On passing sparks it was found that there was a pretty rapid contraction of the volume of gas, but no explosion. The gas left after all action was over was one-fourth the original volume.

Evidently the change consisted in the reduction of nitric oxide by hydrogen—

$$NO + H_2 = N + H_2O.$$

I then took two volumes of nitric oxide and one volume of hydrogen, and on passing a spark through this mixture a pretty sharp explosion took place; white heavy fumes appeared in the tube, together with red fumes of nitric peroxide; the volume of the original gas diminished about 40 per cent., and the water in the eudiometer became strongly acid. This experiment was made over water. I then added to the residue a volume of hydrogen equal to that originally employed, and on passing a spark there was a prompt explosion. In this case no fumes (white or red) were formed.

Being busy at the time, I only made a few rough experiments, and at that time I thought the change in the first explosion consisted, for the most part, in reducing the nitric oxide to nitrous oxide, and this appeared somewhat probable, as the first explosion took place with some difficulty, sometimes requiring several sparks, while in the second stage the inflammation of the gases was easier, and the explosion appeared to have more force.

Returning to the subject some months afterwards, I was unable to get any result at all with similar mixtures of the gases. This appeared somewhat extraordinary, as I used pure nitric oxide in each case (prepared from $FeSO_4$, KNO_3, and H_2SO_4, so as to avoid any trace of nitrous oxide), and everything the same, with the exception of a eudiometer. This new eudiometer had the wires approaching each other within $\frac{1}{8}$ of an inch, while the one formerly used was an older pattern (which had been broken in the interval), in which the wires were fully $\frac{1}{3}$ of an inch apart. Being unable to purchase one of the older kind, I made one with the wires about $\frac{1}{2}$ inch apart, and then the results were similar to those formerly obtained. Another experience may be mentioned here. During my experiments my own coil, giving an inch spark, got damaged, and being unwilling to wait for its repair, I borrowed another, giving a feebler spark. With this, however, no explosion could be got, although the spark would pass readily enough. This coil was then exchanged for one giving a 4-inch spark, and then there was no difficulty in getting an explosion every time, with the mixture already mentioned; and with the new coil a larger proportion of hydrogen could be used than with my

own—a mixture of six volumes of hydrogen and ten volumes of nitric oxide exploding with this coil.

With a diminished pressure of 300 mm. of mercury, no explosion was obtained. On replacing the mercury by water, the same mixture exploded readily. The carefully-dried gases exploded with equal ease to the undried gases.

Possibly with an increased pressure and greater spark, a higher proportion of hydrogen than that mentioned above might have been used.

As regards the explosion of nitric oxide and hydrogen, therefore, my experience may be summed up as follows:—

1. A spark from a feeble coil gives no explosion.

2. A spark from a larger coil gives no explosion if the wires are too close together.

3. No explosion takes place if the pressure is diminished to the extent of 300 mm. of mercury—less than the atmospheric pressure.

4. No explosion takes place if the hydrogen has a greater proportion to the nitric oxide than 6 : 10.

In connection with 1 and 2, it may be interesting to note that Dixon, in a paper read before the Chemical Society, about a year ago, obtained similar results with mixtures of oxygen and cyanogen gases, results which have been attributed to the greater distributing energy of the longer and more vigorous spark. The initial disturbance in these experiments not only determines the explosion, but influences to a considerable extent the resulting products.

We come now to the gases resulting from the explosions. I may state that my first experiments were made over mercury, and the gases resulting from the explosion were determined. The variation was found so great that only pretty general statements can be made. A number of my late experiments were made over water. A number of experiments were generally made with the same mixture—the gases being mixed in a small gasholder, and transferred to the eudiometer.

As illustrating the variation that may occur under like conditions, I may state that in making some experiments with a mixture of nitrous oxide and hydrogen in the proportion of 2 : 1, the residues were mixed and set aside for further examination. On adding the residues from the third explosion to the two first, red fumes were produced, showing that oxygen had been formed in the one case, and nitric oxide left undecomposed in the other.

Sometimes, owing to the greater initial disturbance of the

spark, the flame passes down the tube with greater rapidity, and the explosion is more energetic than at other times. In such cases red fumes are produced, and oxygen is found in the residue.

If the eudiometer is too narrow the explosion may not travel more than a few inches from the wires, and a series of explosions may be got; but nitric oxide is left undecomposed.

Even in a wide tube the explosion may travel slowly down the tube, especially when near the bottom. In such cases nitric oxide may generally be found in the residual gases. With the apparatus mentioned, I have been able to obtain explosions when the volumes were H : NO : : 1 : 5. With one volume of hydrogen to 10 volumes of nitric oxide, no explosion could be obtained. The greatest amount of hydrogen with which I have been able to get an explosion is, 6 vols. H to 10 vols. NO. The explosion then occurs with difficulty, and only when the larger coil I have mentioned is used. Two vols. of H and five vols. of NO explode very readily. The greater number of experiments were made with mixtures of H : NO : : 2 : 5, and H : NO : : 1 : 5.

The gases produced by the explosion vary so considerably that a detailed account would be of little value. More than 50 experiments have been made, and in all but four or five free oxygen has been found in the residue; and this occurs with the smallest volume of hydrogen, as well as the greatest, depending more, I believe, on the force of the explosion and the temperature produced than the proportion of gases present. (For instance, 13 experiments were made with the lowest amount of hydrogen, and in 11 of them oxygen was left.) After explosion the residue left was, on the average, about 60 per cent., the extremes being 44 per cent. and 71 per cent.; and here, again, the proportion of gas left often depends more on the nature of the explosion than on the gases present. With two volumes of nitric oxide and one volume of hydrogen, the change may often be approximately represented by the following equation:—

$$2\,NO + H_2 = H_2O + N_2 + O.$$

The free oxygen is, however, always somewhat less than one-half the amount in the NO; in three cases the volume was determined and the lowest was 40·2 per cent., and the highest a little short of 45 per cent. of the whole—a portion of the NO breaking up as follows:—

$$4\,NO = 2\,NO_2 + N$$

To me the most unlooked-for reaction in these experiments is the production of free oxygen, especially when such a small volume of hydrogen is used.

I have already quoted Henry with reference to the action of hydrocarbons and nitrous oxide. Some hydrocarbons will, however, combine readily enough with NO if submitted to a suitable spark discharge, provided the volume be properly proportioned. Marsh gas, especially, explodes more readily than hydrogen when the volume is not less than one-twentieth or greater than one-eighth of the nitric oxide used. The results show that all the carbon is oxidised to CO_2, and the residue in all my experiments contained free oxygen, this result being accounted for by the vigour of the explosion.

Sulphuretted hydrogen when mixed with nitric oxide can be readily exploded.

Carbonic oxide and nitric oxide did not in any proportion explode. There is a gradual combination, however, which may be represented by—

$$NO + CO = CO_2 + N.$$

XXV.—*Note on the Decomposition of Nitric Oxide in contact with Water and Alkaline Solutions.*

By STEPHEN COOKE, F.C.S.

[Read before the Society, 4th May, 1887.]

PRIESTLEY, in his Experiments on Nitric Oxide, says:—"Being desirous of ascertaining whether nitrous air tended in any degree to a spontaneous decomposition by long standing only, without being in contact with any substance that could be supposed to have an affinity with any constituent part of it, I filled a large phial and corked it very tight, keeping it for the most part with its mouth immersed in a vessel of water, but neglected it and suffered the water to evaporate. However, examining the air about two years afterwards, I found it to have the same power of diminishing common air that freshly-made nitric oxide has." He, however, almost immediately afterwards mentions other experiments in which the nitric oxide appears to have undergone a change on standing a long time; but as he gives oxygen as one of the products formed, there seems to be some mistake in the experiments.

Humboldt and others declared that nitric oxide is decomposed by contact with water, with the formation of nitrate of ammonium.

Davy, however, rejects these experiments, and comes to the following conclusions as the results of his experiments:—"(1) That nitric oxide is not decomposable by water; (2) That the diminution of volume of nitrous gas placed in contact with water is owing to a simple solution of it in that fluid."

Russell and Lapraik (*Jour. Chem. Soc.*, xxiv., 37, 1876) have shown that water and nitric oxide kept at 100° C. for a fortnight, and then for four months at the ordinary temperature, had undergone a contraction of 46·7 per cent.

After making some of my experiments on nitric oxide and hydrogen in presence of platinum, an experiment was tried with the gases alone (*i.e.*, without the platinum), with the result that there was a slow but gradual contraction. On examination of the residual gases, after standing for more than twelve months, it was

found that the hydrogen had no part in the reaction (except retarding it); but the nitric oxide had undergone partial decomposition into HNO_3 and nitrogen, together with a little nitrous oxide.

Two tubes, about ·8 metre long, were filled, one with two volumes of nitric oxide and one volume of hydrogen, the other with equal volumes of the two gases. After standing 54 weeks, the first had undergone a contraction of 230 mm.; and on adding ferrous sulphate, there was a further contraction of 260 mm., leaving 43 mm. of nitrogen and nitrous oxide, the hydrogen being left unchanged. The liquid in the tube was strongly acid, and gave the reactions for nitrous acid. In the tube containing the larger proportion of hydrogen only 150 mm. of gas had disappeared in the same time.

From these experiments it is evident that nitric oxide undergoes a change by merely standing in contact with water. Since these experiments were made the subject has been a little more fully investigated; tubes with platinum were used in some cases, and in others nitric oxide stood over water in tubes without any platinum.

The tubes used were about 400 mm. long. Pure nitric oxide was used. The tubes when filled were kept standing over pure water, or in some cases over mercury with 20 or 30 mm. of water at the top. They were kept in the dark and at the ordinary temperature.

With tubes containing platinum the contraction was gradual but slow, and for the first three or four weeks amounted to 50 mm. per week. After about one-half has disappeared the action gets slower, and in tubes of this kind is not complete for nearly three months. The total contraction will be at least 90 per cent. of the original gas. The residue is chiefly nitrogen, but it also contains a small quantity of nitrous oxide, and a portion of this gas is also found in solution. The water is acid and contains HNO_3.

In a tube similar to the last, but containing no platinum, the action is slower—in the first month the contraction was 100 mm., and towards the end the action is very slow indeed. In nine months the change was complete, the gas remaining being from 10 per cent. to 20 per cent. of the original; the nitric oxide had quite disappeared, the residue consisting of nitrogen and nitrous oxide.

In a tube containing platinum, the action of heat in accelerating the change was tried. Nitric oxide was sealed up in such a tube

with a little water and kept for two hours at 100° C.; there was a contraction of 20 per cent., the residue consisting of nitric oxide, nitrous oxide, and nitrogen.

It is well known that a solution of caustic potash acts gradually on nitric oxide, potassium nitrate and nitrous oxide resulting from the change. The action, however, is very slow, taking some months to complete. Russell and Lapraik have shown that the action is much accelerated by keeping at a boiling temperature. At common temperature, or at 100° C., the action is much hastened by the presence of platinum. A tube of nitric oxide 400 mm. long, containing platinum, was placed in a solution of caustic potash; the action was complete in three weeks, about three-fourths of the original gas disappearing. In a similar tube, sealed up and kept for three hours at 100° C., a like change took place.

XXVI.—*The Arterial system of Vertebrates homologically considered.* By JOHN YULE MACKAY, M.D., Senior Demonstrator of Anatomy, University of Glasgow.

[Read before the Society, 30th March, 1887.]

IN a paper communicated to the *Journal of Anatomy*, January, 1886, Prof. A. Macalister systematises the arrangements of the arteries of man, and draws a comparison between them and a typical arterial scheme founded upon considerations derived from embryology and comparative anatomy. An examination conducted upon such lines provides in many cases a simple explanation of details which, when viewed from the standpoint of human anatomy alone, appear complicated and unintelligible. The development of the arterial system, however, has necessarily been a complicated process, and it is only by the continued accumulation of data that one can hope to understand the relations which subsist between the simple arrangements of lower forms and the highly modified systems of more advanced animals. While agreeing with Prof. Macalister in many cases as to the homological relations of individual arteries, I believe that there is still room for further investigation, and have been led to offer in some instances a different view of development. This is particularly the case in connection with the relations of the branchial arterial arches to the visceral and parietal branches of the longitudinal trunks, and the relations of the branches of the external carotid artery to those of the subclavian and other derivatives of the dorsal longitudinal vessel. I have also added a view of the homologies of the branches of the abdominal and pelvic arteries.

The arteries of a vertebrated animal may be divided into two groups—(1) a primary system consisting of large vessels, and (2) a secondary or branch system passing from the primary to the supply of the body.

THE PRIMARY SYSTEM.

In the early embryonic stage of a vertebrate animal the primary system of vessels consists of the following elements:—(1) Two

longitudinal trunks running the whole length of the body upon the dorsal aspect of the alimentary canal; (2) a longitudinal trunk, single at its origin, but rapidly dividing into two upon the ventral aspect of the alimentary canal, passing from the heart towards the head and reaching as far as the mouth, thus occupying only a limited portion of the length of the body; (3) a system of arches upon the right and left sides of the alimentary canal, passing between the ventral trunks and the dorsal trunks. The ventral trunks, although single behind, are probably to be regarded as originally entirely double and belonging each to one lateral half of the body, the single portion being intimately connected in its development with the heart. In many instances the heart has begun to be formed before the splanchnic walls have met and closed, and it arises then as a double structure, fusion being subsequent.

The arches passing from the ventral to the longitudinal trunks are to be found only in the region between the heart and the head. Prof. Macalister believes that in the region between the heart and the tail the arches are represented by a set of arteries passing from the dorsal longitudinal trunks to the supply of the splanchnic wall, and which, breaking up into capillaries and becoming venous, end in the sub-intestinal vein. He regards the sub-intestinal vein as the thoracic and abdominal portions of the ventral longitudinal trunks. This theoretical conception is to be objected to on several grounds. In the neck where the arches are present the splanchnic wall or alimentary canal is supplied by arteries which, while they appear in all respects similar to the arteries which in the abdomen are distributed to the canal, are perfectly distinct from the primary arches. These branches to the alimentary canal in the neck, breaking up into capillaries, end in veins which have no connection with the ventral longitudinal arterial trunks. In fishes and larval amphibians the arches enter the gills, but in all higher forms each, from the very first, consists of a single vessel, and if, as may be done in the chick, their development be watched, they are found to give off no branches whatever to any part of the body. The arches are to be regarded as a system of vessels intermediate in position between those destined for the supply of the splanchnic and those of the somatic walls, possibly in invertebrate forms, represented by a more extended series, but in the vertebrata found only in the region between the heart and the head. (Pl. VII., Fig. III.)

The dorsal longitudinal trunks, running the whole length of the body, fuse, in the region between the heart and the tail, into a median trunk, the aorta, the flow of blood through which is towards the tail. Between the heart and the head, on the other hand, they remain separate in most vertebrates, and form portions of the carotid system, carrying blood to the head.

In the change from the embryonic to the adult stage the relations of these three sets of vessels are considerably modified. The arches vary in number in different forms. In the embryos of all vertebrates higher than the amphibia there are five. They are numbered in order from the head towards the heart. The fifth arches become upon one or both sides solid cords in the adult, stretching to the aorta from the pulmonary arteries, which are given off from the ventral trunk at the commencement of the fifth arches. The fourth arches become upon one or on both sides aortic, according as the adult form has a right or left aortic arch or both. The third arches become portions of the carotid system upon both sides. The first and second disappear.

The ventral longitudinal trunk is divided by an obliquely longitudinal septum into two compartments, one of them continuous with the fifth arches, the other with the rest. It forms the basal portions of the pulmonary, aortic, and carotid vessels.

While the dorsal longitudinal trunks in their fused portion between the heart and the tail become the aorta, into which the fourth or aortic arches pass, carrying blood towards the tail, the third arches, carrying blood towards the head, enter them, where they remain separate. The portions upon each side between the entrance of the third and fourth arches, in which the direction of the circulation is indeterminate, become obliterated in many forms and disappear, but they remain open in the lacertilia and stretch between the *common carotid* and the aorta.

The question now arises as to what portion of the carotid system is derived from the dorsal longitudinal trunk between the third arch and the head. Rathke* believed that it was only the internal carotid which was to be regarded as a portion of the dorsal longitudinal trunk, and looked on the external carotid as a portion of the ventral longitudinal trunk; and Macalister, building upon this, describes the branches of the external carotid artery as branches of the ventral longitudinal trunk, and believes, upon theoretical

* Rathke, Archiv. f. Anat. und Physiol., 1843.

grounds, that the posterior auricular and occipital arteries represent incomplete arches stretching from the ventral to the dorsal longitudinal trunk. On the other hand, the subclavian artery is regarded, both by Rathke and Macalister, as a branch of the dorsal longitudinal trunk. In the description of the branches of the primary vessels which follow it will be seen that there is a very marked correspondence between the branches of the subclavian artery and those of the external carotid. Further, branches of these two arteries are directly united to one another, as will be seen, by the anastomotic chains which pass between the branches of the dorsal longitudinal trunk so as to render it exceedingly probable that the branches of the external carotid are to be regarded, like those of the subclavian, as derived from the dorsal longitudinal trunk.

The occipital and the superior thyroid arteries anastomose directly with the deep cervical and inferior thyroid arteries from the subclavian. Macalister looks upon the occipital as one of the primary arches, and if this be so, the superior thyroid ought also to be so reckoned. But Macalister also regards the posterior auricular artery as a primary arch, so that if his theories were true there would be representatives of six arches in the mammal, a larger number than has ever been observed in the embryo of any form higher than the amphibia.

The facts of the comparative anatomy of the external carotid artery render it still more probable that it is to be regarded as a branch of the dorsal and not of the ventral longitudinal trunk. In no case except mammals are the branches of the external carotid artery gathered together into a single root. In all other forms they come off at intervals from a trunk common to them and the internal carotid, and which in many cases (birds and crocodiles) runs for a considerable distance along the dorsal aspect of the alimentary canal before giving off any branches to the head. In lacertilia, in some crocodiles, and occasionally in birds, the portions of the dorsal trunk between the third and fourth arches being present, either as patent vessels or solid cords; in all these forms it is easily seen that the greater portion of the common carotid is dorsal in position, and, consequently, that the external carotid branches are derivatives of a dorsal vessel.

While in non-mammalian vertebrates the external carotid branches, as well as the internal carotid artery, are to be regarded as derivatives of the dorsal longitudinal vessel, it will be

seen from the following description of the branch system that whatever opinion may be held as to the dorsal or ventral position of the *basal* portion of the external carotid of mammals, the *branches* of the artery at least correspond to the branches of the dorsal longitudinal vessel.

The Secondary or Branch System.

In studying the branches of the primary trunks it is to be noticed that their arrangement has been modified by the action of two causes. One of these is that in the early embryo the heart is placed close under the head, but in the adult it is removed backwards into the thorax, and the primary arches and portions of the longitudinal trunks to a certain extent participate in the change of position. The chick embryo affords an example. During the fourth day the heart and a portion of the aorta are still in the neck, and the aorta is observed to give off lateral branches to the walls of the neck, but after development is completed and the heart and aorta are found in the thorax, no lateral branches from the aorta pass to the neck. In the descent of the heart and arches the lateral branches from the aorta to the neck have become obliterated. The second modifying cause is the obliteration of the portions of the dorsal longitudinal trunks between the third and fourth arches already alluded to.

Most of the arteries of the body arise from the dorsal longitudinal trunk. A small number take origin from the ventral trunk. None arise from the primary arches. In fishes, where nothing but venous blood passes through the heart, the systemic arteries do not take origin until the blood has become arterialised; that is to say, they are found springing from the vessels beyond the gills, the dorsal longitudinal. In forms higher than fishes, however, where the heart propels both venous and arterial blood, branches are given off from the ventral vessel to a limited portion of the body.

Branches from the Dorsal Primary Trunks: Segmental Branches.—From the dorsal primary trunks branches are given off at intervals corresponding to the segments of the vertebrate body. As it courses through the segment each dorsal trunk may be regarded as giving off branches which pass round the splanchnic and somatic walls to meet in the middle line similar vessels from the other side. Two arterial circles are thus formed, *a visceral* upon the walls of the alimentary canal, and a parietal

upon the body walls. Another set of branches distributed in the embryo to the Wolffian body, and in the adult to structures developed in connection with it, appears to occupy a position intermediate to the two circles; but it seems probable, from the manner in which the Wolffian body is developed, that these arteries are to be regarded as connected more especially with the parietal circle. (Pl. VII., Fig. II.) I have used the word "circle" to denominate the segmental branches of the dorsal longitudinal vessel, in order to avoid confusion between these vessels and the primary arches, which have a similar direction, but occupy a position between the two circles, and are distinct from either. (Pl. VII., Fig. III.)

The visceral circle supplies branches to the alimentary canal and to the organs developed in connection with it. The parietal circle gives branches which radiate from it to the body wall; the most important are (1) a dorsal, (2) a lateral, (3) a ventral. (Fig. II., Pl. VII.)

Longitudinal anastomotic chains connect the circles of successive segments with one another. The most important of these are (1) upon the ventral border; and (2) upon the dorsal border of the alimentary canal; (Pl. VII., Fig. II.); (3) along the ventral aspect of the body wall; (4 and 5) along the ventral and dorsal borders of the neural axis, spinal cord and brain; (6) close to the vertebral column upon the ventral surface of the rib necks; (7) between the rib necks and transverse processes; (8) upon the dorsal aspect of the transverse processes. The last three chains lie in close proximity to one another.

Portions of all the different chains are represented in the human subject. Upon the alimentary canal the two median chains form large vessels on the greater and smaller curvatures of the stomach. Upon the ventral aspect of the body wall the internal mammary and deep epigastric arteries represent a free anastomosis. Upon the neural cylinder the anterior and posterior spinal arteries and the circle of Willis express the anastomotic lines. The three chains which lie close to the vertebræ are but feebly represented in the thoracic and lumbar regions by small vessels, but in the neck they form large arteries—the inferior thyroid, the vertebral, and the deep cervical. In some other forms, however, the last three chains are much more largely developed; in the cetacean class especially, the anastomotic vessels form large plexuses in the thoracic region.

The Visceral Circle.—The following descriptions have special

reference to human anatomy. The arteries which pass to the alimentary canal have in most cases lost their segmental arrangement, and their distribution is only to be explained by reference to the exigencies of development. In some cases they will be found springing directly from the primary longitudinal trunk in the middle line, representing, probably in many instances, a fusion of the vessels of the right and left sides. In other cases their origin is lateral and conjoined with that of the parietal circle, in which circumstances the vessels of the two sides are distinct.

The interference with the segmental arrangement and the accommodation to developmental processes is well marked in the abdomen. The whole of this portion of the tube is supplied by a series of three arteries, the cœliac axis, and the superior and inferior mesenteric arteries, each distributed, as has been pointed out by Professor Cleland,* to a primary loop of the intestine, and arising directly from the aorta in the middle line. (Pl. VII., Fig. I.) The liver and spleen, organs developed in the mesogastrium, receive their blood supply from the cœliac axis.

The pelvic portion of the alimentary canal receives the middle and inferior hæmorrhoidal vessels from the internal iliac and pudic arteries. In these instances the parietal and visceral circles are conjoined at their bases, and the vessels of the right and left sides are distinct. Vesical arteries also pass from the internal iliac to the urinary bladder, which is developed from a portion of the allantoic diverticulum from the intestine. To the portion of the alimentary canal which is contained in the thorax arteries are supplied in a more regular manner. Œsophageal branches, reduced in number to four or five, and in most cases arising directly from the aorta, enter its coats. The lungs, which are developed as a diverticulum, comparable in many respects to the allantois, receive their blood by bronchial arteries, either directly from the aorta, as upon the left side, or from the parietal circle formed by an intercostal artery, as upon the right side.

To the alimentary canal in the neck, the sources of the blood supply have been modified by the combined action of the two causes already noted; the descent of the whole system of vessels into the thorax, obliterating the segmental branches which, in the embryonic stage, spring from the aorta in the neck, and the disappearance of the dorsal longitudinal vessel between the third

* Cleland, *Journal of Anatomy*, iv., 1870.

and fourth primary arches. Under these circumstances, the blood supply to this portion of the intestine is maintained by the enlargement of one of the anastomotic chains. The inferior thyroid artery represents the continuation upwards into the neck of the anastomotic chain between the segmental branches which lies upon the anterior surface of the rib necks. The artery from which it rises —the subclavian—is to be regarded, probably, as representing a fusion of the parietal and visceral circles of two or more segments. The other branches to the alimentary canal spring from the external carotid artery, when that trunk exists, namely, in mammals; they are the superior thyroid, lingual, ascending pharyngeal, and branches from the facial artery. The superior thyroid artery is the continuation downwards from the external carotid of the same anastomotic chain, which continued upwards from the subclavian formed the inferior thyroid artery. The lingual and the ascending pharyngeal represent the visceral circles of still higher segments, while the facial artery supplying visceral and parietal branches is probably to be regarded, like the pudic, and, like the external carotid itself, as representing a basal fusion of the visceral and parietal circles.

The Parietal Circles.—The parietal circles have been least interfered with in the thoracic and lumbar regions, where they form the intercostal and lumbar arteries. These vessels course round the body wall and unite with the anastomotic chains formed by the internal mammary and epigastric arteries. The radiating branches are the dorsal, the lateral, and the anterior. The dorsal branches send twigs into the spinal canal to supply the neural axis, the lateral branches ramify in the body wall, and are in series with the arteries which in the pectoral and pelvic regions enter the limbs.

At the lower end of the abdomen, while the dorsal longitudinal trunk is continued onwards as the middle sacral artery, the parietal and visceral circles, have become fused on each side into one stem—the common iliac artery. The visceral circles have been already noticed. There are five distinct parietal circles—the external iliac, the obturator, the gluteal, the sciatic, and the pudic. The external iliac artery is continued round the body wall, its terminal branch joining the ventral anastomosis formed by the epigastric artery. The lateral branch of the external iliac forms in mammals the femoral artery, and supplies the pelvic limb. The obturator artery passes round the somatic wall, and is joined

by anastomotic branches to the epigastric artery; in instances where the root of the obturator artery fails, it arises from the epigastric by a further prolongation downwards of the ventral anastomotic chain. Lateral branches of the sciatic artery are prolonged for some distance with the nerves; and in birds and reptiles these form the main supply of the limb.

At the upper end of the thorax, the subclavian artery represents a fusion, probably, of the visceral and parietal circles of the last cervical and first thoracic segments. The parietal branches sweeping round the body wall terminate in the ventral anastomotic chain as the root of the internal mammary and the first intercostal artery. One lateral branch is prolonged as the axillary artery into the limb, and others are represented by the tranverse cervical and supra-scapular.

In the neck, owing to the obliteration of the dorsal longitudinal vessel, the origin of the segmental circles is transferred to the longitudinal anastomotic chains. Three of these are present connected below with the subclavian and above with the carotid artery. They are the inferior thyroid joining the superior thyroid, the vertebral joining the internal carotid, and the deep cervical joining the occipital. (Pl. VII., Fig. I.)

The external carotid artery may probably be regarded as a stem of secondary formation, uniting the origins of visceral and parietal circles of several segments. This view is corroborated by the consideration that the external carotid trunk is peculiar to mammals. Among the parietal branches the occipital, continued into anastomosis with the chain which lies on the dorsal aspect of the transverse processes, is to be regarded as dorsal. The internal carotid, after leaving the neck, corresponds to an enlarged spinal branch.

The Intermediate Arteries.—The vessels which, springing from the abdominal aorta, supply the Wolffian body and its derivative organs may be so termed. They are the supra-renal, the renal, and the spermatic or ovarian. Probably in the pelvis the uterine and vaginal have a similar origin. These vessels join in a subperitoneal anastomosis with the branches of the parietal circle.

Branches of the Ventral Longitudinal Trunk.—If the branches of the external carotid artery be considered as belonging to the dorsal trunk, the branches of the ventral trunk are few in number. They are represented by the pulmonary arteries, the coronary *arteries of* the heart, and the occasional thyroidea ima. In

some mammals, as the cetacean group, the thyroidea ima is constant. In forms lower than mammals the branches from the ventral trunk are large and important. They are described along with the comparative anatomy of the subclavian artery in the next section.

Comparative Anatomy of the Anastomotic Chains between the Subclavian and Carotid Arteries.

The subclavian artery, although in mammals springing from the dorsal longitudinal vessel, is yet in some other forms a branch of the ventral longitudinal trunk. This second mode of origin is to be found in birds and in crocodilian and chelonian reptiles—in which groups the subclavian is found to stretch outwards to the limbs, from the ventral margin of the base of the carotid stem, crossing in its course, superficial or ventral, to the pneumogastric nerve and jugular vein. There are thus two vessels which, in different circumstances, may be prolonged into the pectoral limb—one from the dorsal trunk found in most mammals, in lacertilian reptiles, and in amphibians, the other from the ventral vessel in birds and crocodilian and chelonian reptiles. In most cases both these arteries are to be found co-existing, although but one reaches the limb. Among mammals, in the porpoise and in other cetacean animals, it is the artery from the ventral trunk which supplies the limb, but the artery from the dorsal trunk is present as a very large vessel—the posterior thoracic—distributing its branches chiefly to the great thoracic arterial rete, but also giving off branches to the neck, which correspond to the inferior thyroid and deep cervical of the human subclavian. In lizards both vessels are present, but, as in the human subject, it is the dorsal one which is prolonged into the limb, the ventral one losing itself in branches among the scapular muscles. It is important to notice that in all cases where the two arteries are to be found they anastomose freely with one another in the lateral body wall. The comparative anatomy of the subclavian artery may thus be briefly summarised:—There are two vessels, one arises from the ventral longitudinal trunk and runs round the body wall in a dorsal direction, the other arises from the dorsal trunk and runs round the body wall in a ventral direction; they anastomose in the body wall, and at the place of anastomosis the branch to the limb arises. (Pl. VII., Fig. III.) In most cases both roots are present, one or other being the larger. On account of the free anastomosis

in the lateral wall, when one root is very much reduced in size, some of its more external branches may be transferred to the other.

The branches specially belonging to the ventral root are, compared with those of the dorsal root, unimportant. From its inner end an artery corresponding to the thyroidea ima of human anatomy is supplied to the trachea and œsophagus. In amphibians and lacertilian reptiles this artery is prolonged to the tongue, but, in the successively higher stages it is reduced in size, until finally, as in most mammals, it disappears altogether. Other branches from the ventral subclavian are (2) a connection with the internal mammary upon the ventral aspect of the body wall, and (3) a branch to the dorso-lateral aspect of the neck anastomosing with arteries from the dorsal root and from the carotid. From the dorsal root of the subclavian artery the three anastomotic chains already noticed are continued into the neck. In the different groups of vertebrates much variation is found in respect of the apparent origin and relative development of these three vessels, but in every case an explanation may be found by an application of the principles already laid down.

In the amphibia, in which the subclavian takes origin by its dorsal root, after the manner of the mammalian artery, only one of the three anastomotic chains is enlarged and prolonged into the neck. A vessel corresponding to the deep cervical artery passes to the head among the dorsal muscles of the neck. This vessel should anastomose with an occipital artery from the carotid, but no such vessel being present, the deep cervical of the subclavian is itself continued forwards to the back of the head as an occipital artery. The origin of an occipital artery from the subclavian is easily explained by reference to the anastomotic chain, but it is rare to find the root from the carotid absent altogether. A very similar state of parts, however, is found among mammals in the cetacean group.*

In the chamaeleonidæ among the reptiles, while, as in the amphibia, only one of the three anastomosic chains is specially enlarged, the vessel which corresponds to the inferior thyroid artery of mammals plays the important part. The subclavian arises by its dorsal root and gives off, close to its origin, a vessel—

* Arterial System of Porpoise. *Proceedings* of the Philosophical Society of Glasgow, 1886.

the ascending cervical—which passes forwards nearly to the base of the skull below the cervical transverse processes, and detaches twigs to the œsophagus, the subvertebral muscles, the spinal cord, and the dorsal muscles of the neck.

Among the chelonian reptiles a complication is met with. The subclavian arises by its ventral root and passes round the body wall in a dorsal direction. The dorsal root and some of the intercostal arteries behind it have disappeared, but the circulation is maintained from the ventral vessel by the anastomosis in the lateral body wall. The ventral vessel is therefore continued right round the body wall and terminates in the longitudinal anastomotic chains which appear to be continued forwards to the head and backwards towards the tail from a ventral subclavian artery. Of the three anastomotic chains prolonged into the neck, only one is specially enlarged. This vessel corresponds to the deep cervical of human anatomy and runs forwards among the dorsal muscles of the neck to terminate in anastomosis with the occipital artery from the carotid.

Among the crocodilian reptiles further complications are met with. The subclavian arises by its ventral root, the dorsal root being very much reduced in size. The ventral subclavian, as in the chelonian passes right round the body wall into the longitudinal anastomotic chains. Here, as in the other forms, only one of the three lines is specially enlarged, and in this case it is that between the rib necks and transverse processes, corresponding to the human vertebral artery. The first parietal circle which arises from the aorta is supplied to one of the lower intercostal spaces, but an anastomotic chain passes forwards from it, supplying the spaces in front. This is continued into the neck as the vertebral artery, but it is reinforced at the anterior end of the thorax by a branch from the subclavian, corresponding to the root of the deep cervical artery in the chelonian reptiles, while in the neck the vertebral artery receives a third root from the carotid portion of the dorsal longitudinal vessel, which in crocodiles and in birds runs forward for a considerable distance close to the middle line before dividing into its external and internal branches. In the crocodile the anastomotic chain which forms the vertebral artery is thus entered by three different roots.

The manner in which the vertebral artery of the crocodile terminates is interesting. It is the only one of the three anastomotic chains, which is specially enlarged, and in the thoracic portion of its

course it gives off a number of intercostal or parietal arteries. In the neck these are still given off, although much reduced in size, and immediately behind the skull it ends in a double manner. Its larger portion, like the dorsal branch of a parietal artery, terminates in anastomosis with the occipital artery, resembling in this respect the human deep cervical, while by far the smaller portion, after the manner of the spinal branch of a parietal artery, passes on to the neural axis to anastomose with the internal branch of the carotid artery like the human vertebral.

In birds, as in all the other forms yet considered, only one of the three anastomotic chains is specially enlarged, and, as in crocodilian reptiles, it is the vertebral artery which is prolonged into the neck. The subclavian artery arises by its ventral root, and, as in the crocodile, the vertebral artery should take origin by roots from three distinct places, but of these two are so reduced in size as to appear absent. The main root is that from the carotid artery, or, in other words, from the carotid portion of the dorsal longitudinal vessel, Of the other roots, that from the first aortic intercostal artery is represented by a fine anastomotic thread between the two vessels, while that from the ventral subclavian continued round the body wall into the anastomotic chain is not to be found. In a number of dissections, made for the purpose of tracing the connection between the subclavian and vertebral arteries, while I was able to follow their branches into close proximity to one another, I could not demonstrate actual anastomosis. The vertebral artery of birds terminates, like that of the crocodile, in a double manner, the larger portion inosculating with the occipital, the smaller with the internal carotid artery.

In mammals, in which the subclavian arises by its dorsal root, the type followed is that of the human subject, in which, as has already been explained, the three anastomotic chains are represented. The cetacean class forms an exception. Here both ventral and dorsal roots are present, the branches to the limb passing from the ventral vessel. From the dorsal vessel, however, two anastomotic chains pass into the neck, corresponding respectively to the inferior thyroid and deep cervical of the human subject, the vertebral being unrepresented.

There are many varieties in the different groups of mammals in the origin of the vertebral artery, but in most cases it arises either directly from the subclavian, or from the aorta in its immediate *vicinity*. In the human subject, too, while the vessel normally

takes origin from the subclavian, it is sometimes found springing from the aortic arch. A very interesting relation of parts is exhibited in a preparation of the arteries of the hooded seal (*Stemmatopus cristatus*) in Professor Cleland's Museum. The vertebral artery (Pl. VIII.) in this animal, while arising from the subclavian, is reinforced by a considerable longitudinal anastomotic chain lying between transverse processes and necks of ribs, and springing from a trunk common to the first and second aortic intercostal arteries. These relations call to mind the anatomy of the vertebral artery in the crocodile, but there is this difference to be noted, namely, the subclavian artery of the seal is dorsal, that of the crocodile is ventral in origin.

In the human subject Mr. A. M. Paterson* has described a vertebral artery arising, not from the subclavian, but abnormally from the first aortic intercostal artery. Such a case as this is obviously to be explained by the failure of the branch from the subclavian artery to the vertebral anastomotic chain, which in the circumstances has had to depend for its supply of blood upon the next parietal circle—the first aortic intercostal.

DESCRIPTION OF PLATES.

Plate VII., Fig. I.

I., II., III., IV., V.—The primary arches. Between I. and V., the ventral longitudinal trunk.

Ao.	Aorta.	*C.c.*	Common carotid.

Branches of the dorsal longitudinal trunk.

I.c.	Internal carotid.	*c.a.*	cœliac axis.
occ.	occipital.	*s.m.*	superior mesenteric.
l.	lingual.	*i.m.*	inferior mesenteric.
f.	facial.	*e.i.*	external iliac.
s.th.	superior thyroid.	*ob.*	obturator.
s.	subclavian.	*gl.*	gluteal.
i.th.	inferior thyroid.	*sc.*	sciatic.
v.	vertebral.	*pu.*	pudic.
d.c.	deep cervical.	*h.*	hæmorrhoidal.
in.	intercostal.	*i.m.*	internal mammary.
1,2,3.	anastomotic chains.		

* Paterson, *Journal of Anatomy*, No. xviii., 1883-84.

FIG. II.

v.c.	visceral circle.	*d.*	dorsal anastomosis on neural cylinder.
p.c.	parietal circle.	*e.*	ventral anastomosis on neural cylinder.
x.	intermediate arteries.	*f.*	anastomotic chain, dorsal to transverse processes.
l.	lateral branch.	*g.*	anastomotic chain between rib necks and transverse processes.
a.	dorsal anastomosis on alimentary canal.	*h.*	anastomotic chain, ventral to transverse processes.
b.	ventral anastomosis on alimentary canal.		
c.	ventral anastomosis on body wall.		

FIG. III.

d.t.	dorsal trunk.	*p.c.*	parietal circle from dorsal and ventral trunks.
v.t.	ventral trunk.	*p.a.*	primary arch.
v.c.	visceral circle.	*l.*	lateral branches.

PLATE VIII.

ARTERIES OF HOODED SEAL (*Stemmatopus cristatus*).

Ao.	Aorta.	*Int. 1.*	1st aortic intercostal.
In.	Innominate.	*Int. 2.*	2nd ,, ,,
C.	Common carotid.	*Int. 3.*	3rd ,, ,,
S.	Subclavian.	*Between Int. 1 and V.*—	Anastomotic chain between vertebral and first aortic intercostal.
Cer.	Cervical branch of subclavian.		
Ax.	Axillary.		
I.m.	Internal mammary.	*Cor.*	Coronary artery.
V.	Vertebral.	*Œs.*	Œsophagual branch.

FIG. I.

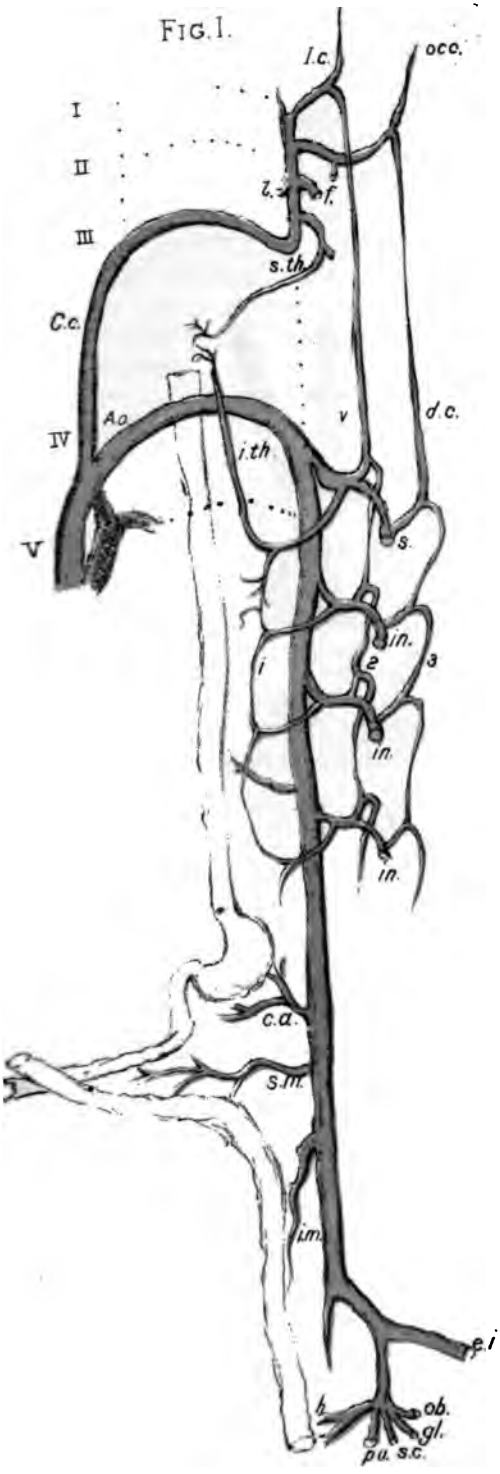


FIG. II.

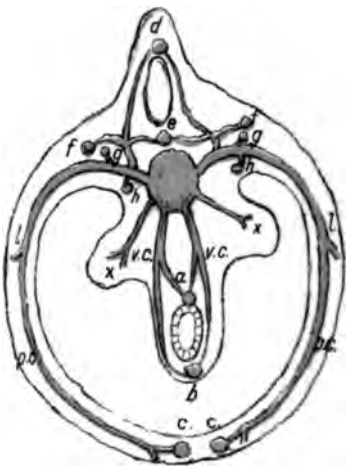
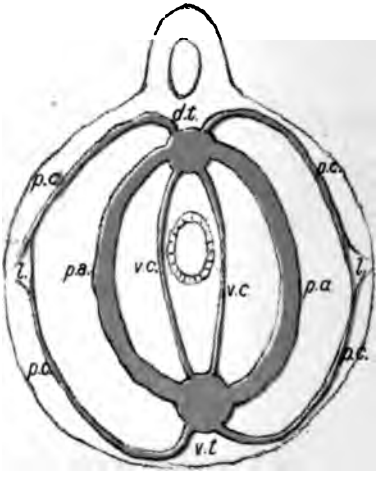
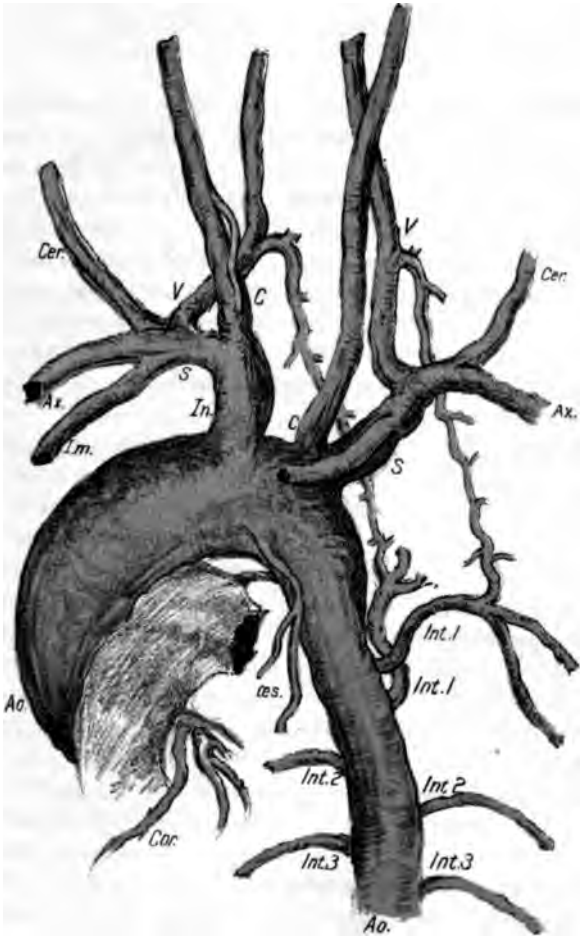


FIG. III.





Maclure, Macdonald & Co.

XXVII.—*Note on a Morphological Peculiarity of Cordyline Australis.* By Professor F. O. BOWER, D.Sc., F.L.S.

[Read before the Society, 30th March, 1887.]

ON numerous old plants of the *Cordyline Australis* growing in the Peradeniya Gardens a morphological peculiarity is to be observed which I am not aware of having been remarked hitherto. In the case of those axes which grow erect nothing extraordinary is to be seen; but when, as is often the case, owing to the weight of the terminal crown of leaves and insufficient strength of the supporting axis, the stem assumed an oblique or horizontal position, lateral shoots were to be observed originating from the lower side of the main axis, and directed vertically downwards. Their length varied in the cases observed, being sometimes as much as 9 or 10 inches. Examination showed that they bear numerous scale leaves, but never foliage leaves. They are also provided with numerous small roots, which, in the natural condition, that is to say, as seen suspended in the air, were never more than about $\frac{1}{8}$th inch in length.

It seemed most probable that the function of these downward-growing shoots would be to gain access to the soil, root themselves in it, and thus afford both mechanical and physiological support to the relatively weak main axis; but, unfortunately, none of them had reached the soil, or, indeed, were anywhere near it. I accordingly determined to bring the soil up to their level and see what the result would be; and this was done by hanging pots of ordinary soil from the main axis at such a level that the downward growing axis should touch the soil or be embedded in it. These cultures were started on January 11th, 1886. Though the soil was kept well watered the progress of the cultures was slow, and on March 3rd, when my visit to Peradeniya was drawing to a close, the pots were removed, when the results were roughly as follow:—

1st Specimen.—In this case the tip of the terminal bud just touched the soil, but the bud was not immersed. No roots penetrated the soil, and even after the two months the shoot was hardly any longer than before. This illustrates the very slow rate of growth of these positively geotropic shoots.

2nd Specimen.—The tip of the bud was buried about 1 inch deep in the soil, and the shoot had increased slightly in length during the period of the experiment, but did not show any sign of upward curvature. A strong root-system, which had been developed from the apical portion of the shoot, ramified freely throughout the soil in the pot.

3rd and 4th Specimens.—The conditions were similar to those of No. 2, and the results were in the main the same; in both cases, however, the terminal bud showed signs of an upward curvature, but not sufficient to decide whether it would ultimately rise above the soil as a foliage shoot. Thus it would appear that when the downward-growing shoots obtain access to the soil they form a strong root-system, at the same time showing a tendency to turn upwards.

A careful examination of the origin of these shoots showed that in all observed cases they occupy an axillary position. Of the whole series of axillary buds formed on the oblique main shoots, those which are seated on the upper surface and sides are for the most part permanently dormant; but those on the lower surface often develop as these downward-growing shoots, either immediately, in which case they burst through the base of the sheath of the subtending leaf, or they undergo at first a period of comparative dormancy. They are exogenous in their origin, though this is in some cases difficult to prove, owing to the first leaves being almost completely sheathing, and leaving only a very small aperture. Thus a number of sections might be cut which would not traverse the aperture, and these would give the impression of an endogenous origin, though a careful observation of the whole series of sections through a bud would not bear out this conclusion.

The roots which are formed on these downward-growing shoots are of endogenous origin. They usually arise immediately above the insertion of a leaf, but not in the median plane of the leaf, as is the case with the axillary buds. They appear laterally, and usually at points where the margins of the insertion of two leaves overlap.

Taking all the facts together, it is clear that these pendulous shoots are the result of the special development of parts which, in point of origin, arise in the ordinary succession. From the simple experiment just described it may be legitimately concluded that, whatever the fate of their terminal buds may be, the

Fig. I

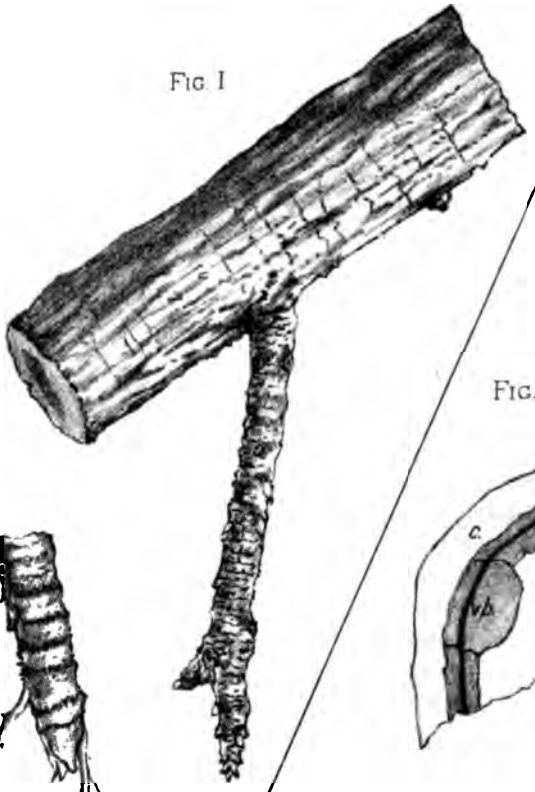


Fig. II.

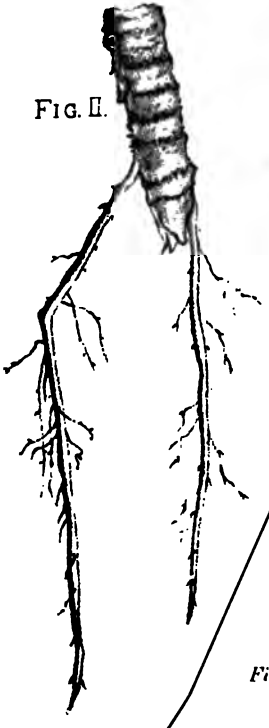


Fig. IX.

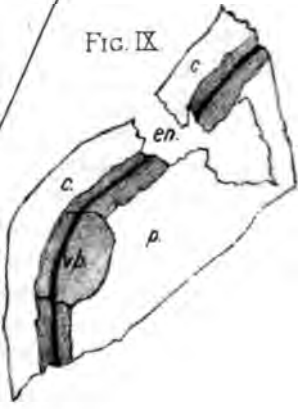


Fig. V

x 25

Fig. VI.

x 25

Fig. VII.

x 25

Fig. VIII.

x 25

Figs. V.—IX. are described on page 226, and form part of Plate X.

function of these downward-growing shoots is to afford both mechanical and physiological support to those weak and obliquely-growing axes which are incapable of holding erect their terminal tuft of leaves; and here it may be remarked that the phenomenon is more common in those plants which had grown under a dense shade. Under such conditions extreme growth in length of axis, and insufficient thickening, are to be expected, and, consequently, in those cases increased mechanical support would be more needed.

It is already well known, and made the more familiar from the experiments of Sachs ("Stoff und Form," *Würzburg Arb. II.*, p. 475, &c.), that *Cordyline*, in common with other arborescent Liliaceæ, bears underground shoots, which grow vertically downwards, bear scale leaves, and give rise also to numerous roots. To these, no doubt, the aerial shoots already described correspond in their nature and origin, but still their attachment at various points on the aerial shoots and their downward growth through the air give them a special interest, while in point of function they clearly differ from those shoots which are underground, just as the aerial roots of the Mangroves, of *Pandanus*, species of *Ficus*, *Clusia*, &c., differ in function from the ordinary underground roots of those plants. In these plants, as in *Cordyline*, the chief functions are those of mechanical as well as physiological support. It is to be remarked, however, that though the result in these cases is the same, it is brought about by members of a different morphological category, and thus we have a further example of the various adaptability of members to the requirements of the plant as a whole. Lastly, the case of *Selaginella* will naturally occur to the mind in connection with such a case as this of *Cordyline*. While the morphological character of the rhizophores remains a puzzle, still it is clear that in their function as root-bearing organs, while not roots themselves, they are a nearer parallel to the downward-growing aerial shoots of *Cordyline* than any of the other examples above cited.

EXPLANATION OF FIGURES.

PLATE IX.

Fig. I.—Portion of obliquely-growing axis of Cordyline, bearing a lateral shoot directed vertically downwards.

Fig. II.—Part of a vertically downward-growing shoot, after cultivation in soil for about two months: a strong root-system has been developed from it.

XXVIII.—*On Humboldtia laurifolia*, Vahl, *as a Myrmekophilous Plant.* By Prof. F. O. Bower, D.Sc., F.L.S.

[Read before the Society, 30th March, 1887.]

The subject of the mutual relations of ants and plants, which has recently commanded considerable attention, is by no means a novel one. The literature of the subject dates from the 17th century onwards, and it is quite possible that among the accounts of voyages, still earlier references may be found to such phenomena which are as easily observed as they are interesting. The most comprehensive work on the subject is one recently published by Beccari (Malesia, Vol. II., fasc. i., ii., 1884; fasc. iii., 1885), relating to myrmekophilous plants of the Malayan and Papuan Archipelago, of which the most striking genera are the now familiar *Myrmecodia* and *Hydnophytum*. Of these genera about fifty species have now been described by Beccari as affording, in peculiar cavities in the more or less swollen stem, an asylum for divers species of ants. Various other genera, however, of plants, far removed from the *Rubiaceæ* (e.g., *Leguminosæ*, *Palmæ*, *Euphorbiaceæ*), also afford shelter to ants; further, it is to be noted that the part inhabited is by no means uniform, it being sometimes the stipular thorns (*Acacia cornigera*), sometimes the ochrea (*Korthalsia*), or even the lowest pair of pinnæ (*Calamus amplectens*). In considering the probable meaning of these relations of ants and plants, if we remember that we have thus to deal with plants of very different natural families, some of which are independent, others epiphytic, with divers parts of those plants, and, as stated by Beccari, with ants of different genera, it must, I think, be admitted that each example should be studied separately, and that the questions of origin of the inhabited hollows, and of the mutual advantage from the symbiosis, should be considered independently in each case.

It is interesting to find in the account of the first voyage of Captain Cook (A.D., 1768-1771), in which he was accompanied by Sir Joseph Banks, the following passages, which not only record

the observation of a myrmekophilous plant, but also express a view as to the origin of the symbiosis in the case observed (p. 91). "On another tree they saw black ants, which perforated all the twigs, and after they had eaten out the pith, formed their lodging in the hollows which contained it, yet the trees were in a flourishing condition;" and again, on p. 118-119, in describing the different sorts of ants observed, we find—"the second species of ants here are black, and live in the inside of the branches, after they have worked out the pith." These observations were made near Cape Capricorn, on the East coast of Australia, of which I understand that *Humboldtia laurifolia* is not native, though the description might well apply to it, with the exception of the point that the ants take the initiative in the perforation of the stems.* In the case of *Humboldtia*, as we shall presently see, it is probable that the ants assist in the hollowing out of the internodes; still the plants, by a peculiarity of their development, take the initiative, and offer to the ants an opportunity of accommodation of which they are not slow to avail themselves.

With regard to the views more recently propounded as to the relations of the ants and plants, it may be briefly stated that, from a study of *Myrmecodia*, Treub came to the conclusion that the galleries which permeate the swollen stem are formed naturally by the plant, not by the ants, and that they are merely useful to the plant as bringing about a sort of ventilation of the inner tissues; further, that the ants find in them convenient house-room. Beccari, on the other hand, holds that, in this instance, the presence of the ants is necessary, even in the young germinating plants, to produce by their constant gnawing a stimulation of the tissues, which shall result in the formation of a succulent swollen stem, to serve in the dry season as a store of fluid. Bearing these conflicting views in mind, we may now pass on to consider the plant which is the subject of this paper, and inquire, 1st, into the origin of the cavities; 2nd, into the relations which subsist between the ants and the plant.

During a recent visit to Ceylon, my attention was drawn by Dr. Trimen to the plant *Humboldtia laurifolia*, a native of Ceylon and the Malabar coast. In this tree the internodes of the higher twigs are enlarged, and are hollow when mature, the cavities being constantly inhabited by small black ants.

* The genus *Humboldtia* is a small one, one species being native of tropical Africa, the rest of Ceylon, and the Indian peninsula.

Taking a young shoot of the current year, the lowest internodes of the stem appear normal, but the upper ones are enlarged, so as to assume an obconical form, and a length of 3–6 inches. In quite young shoots these internodes will be found to be solid and filled with a healthy and bulky pith. As the internode grows older, a longitudinal slit appears at its upper extremity, and situated between the large foliaceous stipules, on the side of the axis opposite to the insertion of the leaf. Usually it does not occupy an exactly median position between the two stipules, but appears either on one side or the other of a vascular bundle which runs up the internode and occupies the median line. Externally the slit appears about $\frac{1}{8}$-inch in length; its margins are slightly irregular, and as the internode grows older they protrude outwards, while the tissue of the pith within frequently shows a convex bulging. These points lend probability to the view that the slit is produced by longitudinal rupture of the tissues, owing to pressure from within rather than injury from without. This view is supported by the appearance presented by sections cut so as to pass transversely through the lips; in these the edges of the slit show an irregular outline, the irregularities of the two sides often corresponding to one another. This clearly points to rupture as the origin of the slit, and not gnawing from without. No traces of the latter have been observed on the slits on young internodes. Further support of this view may be obtained from the study of transverse sections of the young stem at the level where the slit would appear: these show that the band of tissues outside the pith is narrowest at that side of the stem where the slit appears, and it is presumably there that the least resistance to internal tension would be found. Judging from the width of the band of tissues, the point of least resistance is on one side or other of the large median bundle, and that is the very point where the slit is actually formed; thus, there is an *à priori* probability that the slit is due to rupture, and this is in complete accord with the observations on slits recently formed. (Fig. IX., Plate X.)

Shortly after the slit appears, the pith of the corresponding internode turns brown, and often becomes partially separated during the elongation of the internode into transverse diaphragms. It is apparently after this change has taken place that the ants begin their work. Notwithstanding the formation of a callus which would tend to close the slit, the ants continue to

gain access through it to the pith within: this in its partially decomposed and brown condition they remove, and I have no doubt that they engage themselves actively in this duty, since, close by the slit in internodes of a suitable age, I have repeatedly found small heaps of the brown substance, which cannot but be recognised as the pith removed from the hollow internode. This clearing of the pith while the internode itself is extending results in the formation of a hollow space of considerable size, in which the ants are to be found in large numbers, while they may constantly be seen entering and passing out by the slit: this ultimately assumes an almost circular form with rounded callous lips. The corky development of callus at the lips is extended further into the cavity so that the whole is finally lined by a corky layer, similar to that described for the galleries of *Myrmecodia*. It would thus appear from the study of their development that the ants do not take the initiative in the formation of the cavities, as implied in the case described in "Cook's Voyages," but are ready to take advantage of and improve upon certain natural peculiarities of development of the plant itself.

Of the myrmekophilous plants cited by Beccari, that most nearly corresponding to *Humboldtia* is *Clerodendron fistulosum*, a new species; here also the internodes are swollen, and hollowed, and inhabited by ants, which gain access to the interior of the slit-like holes, *two* of which are situated, one on either side, at the upper end of each internode. Beccari is of opinion that both the swollen form of the internodes and the first origin of the holes have become inherited characters of the species, as an adaptation to the requirements of the protecting ants. Somewhat similar slit-like holes are to be found in *Myristica myrmecophila*, also a new species. The form of the orifice in this case also would suggest that the initiative in their formation is taken by the plant.

Another somewhat similar case has been recognised by Burbidge in North Borneo, and specimens are lodged in the British Museum: it is in *Nepenthes bicalcarata* in which the cylindrical portion of the leaf immediately below the urn is perforated by a round hole, which leads into a central cavity, in which it is stated that ants find a home. On examining a living plant of this species at Kew, there are to be seen lenticel-like spots, which might very well serve as starting points for the ants to perforate the more resistant outer tissues; but in the case of the plant at Kew, no open channels were seen, so that we may conclude that here again the ants do

not find their homes ready made, but take advantage of facilities offered by the plant, which they then turn to their own uses.

Returning now to *Humboldtia laurifolia*, there are seated at the base of the leaf-stalk large foliaceous stipules of peculiar form. These consist of two parts on either side—1st, a lower sagittate portion, with a rather broad oblique insertion, and having 4-6 dark-looking glands on the upper surface; and, 2nd, an ovate-lanceolate portion, also with a broad insertion, and having one or more glands seated irregularly on the lower surface, near to the apex. Though in the mature state these present the appearance of two distinct pairs of appendages, the one pair being inserted above the other, a study of their development leads to the conclusion that they originate from only *two* outgrowths from the base of the phyllopodium, which appear before the pinnæ, and may themselves be regarded as pecularly developed "basal pinnæ." They are from the first flattened; the apical growth is at first the strongest, but later a basal growth begins, resulting in the formation of basal flaps, directed downwards. These soon assume the sagittate form, and develop the glands on their upper surface: they are thus to be regarded merely as basal appendages, or auricles, attached to the peculiarly-formed stipules, the upper limbs of which grow up meanwhile and enclose and protect the young apical bud. Though differing slightly in the details of their conformation, these basal flaps, or auricles, may be compared with those appendages to be found attached to the bases of the sepals of the common pansy (*Viola tricolor*): the mode of development appears also in this case to be fundamentally the same.

The glands above mentioned are of considerable size and dark colour: those on the stipular auricles are arranged in a row on the upper surface, near the insertion, and, accordingly, are close to the hole by which the ants enter: those on the limbs of the stipules and those which are also found in small numbers on the pinnæ, open upon the lower surface, and are situated near to the apex of each, being variable both in number and position. As regards their structure, the glands when mature are slightly depressed, the depression being surrounded by a projecting lip. The glandular tissue itself is an almost spherical mass of small thin-walled cells, with large nuclei and plentiful protoplasm: this mass is limited by a somewhat irregular sheath of brownish cells, and it is derived partly from the dermatogen (which divides here both peri- and *anti-clinally*), but chiefly from the subjacent tissues. There is no

development of glandular hairs on the surface of the gland. This description will suffice to show that the structure of these glands is different from that of the stipular glands of *Vicia*. Unfortunately, when on the spot, I did not observe the movements of the ants with regard to the glands, and am therefore not in a position to state whether their secretion is actually made use of by them; but if we remember parallel examples of myrmekophilous plants, it would seem very probable that this is the case.

It has been pointed out in other examples of these peculiar relations of ants and plants that the advantages of the symbiosis are mutual; thus, in *Acacia cornigera*, while the ants gain both food and lodging from the plant, they are said to afford it protection against another kind of ant which gnaws the tissues: it may then be asked—Is the advantage mutual in the case of *Humboldtia laurifolia* also? Though I am not in a position to deny it, I have no reason to think that it is. Whatever may be the relation of the ants to other animals, they may be allowed to run freely over the human hand without discomfort, even when they have been rudely disturbed in their homes; thus their presence cannot be considered as generally protective. Further, it has been suggested by Beccari that in *Myrmecodia* the peg-shaped or wart-like projections, which protrude into the galleries, have an absorbing function, and that they are of advantage in taking into the plant and utilizing the refuse of the ants. However that may be in the case of *Myrmecodia*, we find no such structure in *Humboldtia* to which any such function can be ascribed: in brief, the presence of the ants does not in this case appear to be any advantage to the plant. But on the other hand, the advantages to the ants are obvious: not only are they provided with house-room at a very slight expense of labour to themselves, but it may be fairly assumed that from the glands on the stipules and leaves they derive a supply of food-stuffs. Taking all the facts into consideration, I am inclined to think that in *Humboldtia* the plant offers fortuitous hospitality, which is eagerly accepted by the ants. This conclusion would be in accordance with that of Treub in the case of *Myrmecodia*, but would not accord with the views of Beccari, recently expressed, as to the relations of ants and plants, namely—that the glandular and other developments taken advantage of by ants are an inherited response to stimuli originating by the gnawing action of the ants themselves in former periods. As against this view it may be mentioned that glandular developments are frequently to be found on the

leaves of plants without any apparent relation to the visits of insects. We have, as far as I am aware, no evidence that glandular developments do follow continued and repeated gnawing, while rupture of tissues occurs not unfrequently, especially in fruits and succulent shoots, without such relation. It appears to me more probable that the presence of glands and convenient ruptures of the outer tissues are a strange coincidence, rather than due to any deeper cause, and that the ants have not been slow to turn the coincidence to their own uses.

DESCRIPTION OF THE FIGURES.

Plate X.

Fig. I.—Internode of *Humboldtia: st* = stipules; *s* = stem; *en* = entrance to hollow; *h* = hollow (natural size).

Fig. II.—Internode halved longitudinally: *gl* = glands; *ph* = phyllopodium (natural size).

Fig. III.—Part of a young internode not yet hollowed.

Figs. IV.-VIII.—Various stages of development of the leaf, illustrating the mode of formation of the stipules (x 25).

Fig. IX.—Transverse section through a young slit, showing signs of its origin by rupture of the tissues.

I.

Fig. II.

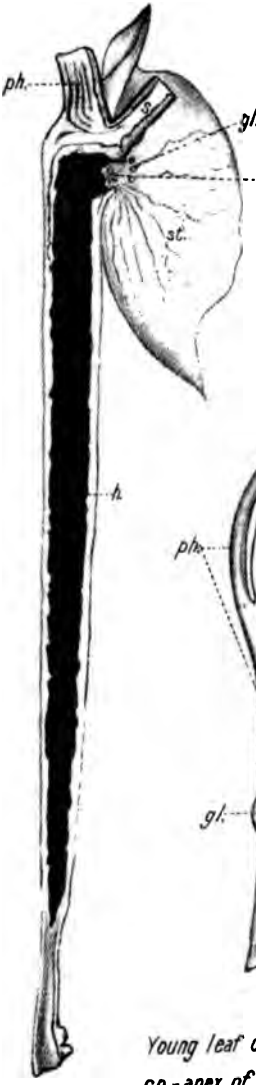
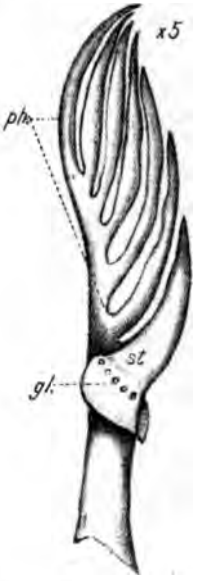


Fig. IV.



Young leaf of Humboldtia

cp = apex of phyltopodin

p - primæ

st - stipules with peculiar basal growth

of sep = of pansy

XXIX.—*On Biological Teaching in Germany and in this Country.*

By J. H. Fullarton, M.A., B.Sc.

[Read before the Society, 4th May, 1887.]

On every hand we are hearing of the superiority of the Technical and Scientific Education of Germany over that in Britain, and our prophets are picturing a somewhat dismal future for those branches whose advance is clearly bound up with the progress of science. It is not my province, did I even find myself capable of forming a judgment on the great technical problems which commercial men are endeavouring to solve, to enter on this vast subject. But there are other questions which equally concern the welfare of the community, where it is advisable that those engaged in biological studies should be heard. Such questions naturally recur to us, as where the health of a people is affected directly by the presence of animal and vegetable parasites. The increase of the food supply, as, for example, in the productiveness of the sea fauna, or in the efforts for combating the ravages of such funguses as the potato fungus or the salmon fungus, is intimately connected with our prosperity as a nation. The examination of our cereals, so that only those which will yield the greatest number of fertile seeds, enabling us thereby to utilise the less fertile in other ways, can only be undertaken by a biologist who is skilled in botanical science. That it is therefore of the first importance that we should foster all sciences which will help us to attain to a solution of problems like these, is admitted by all whose minds are alive to the magnitude of the interests involved.

What I have to say as regards the educational facilities afforded in Germany and in this country will be chiefly directed to the zoological side of the question; and for the sake of comparison, I will select a well-equipped university, such as that of Leipzig, the number of whose students, 3,108 in 1885-6, is a medium between

that of Glasgow, 2,241, and of Edinburgh, 3,535, during the corresponding period. As regards the number pursuing medical studies, Glasgow and Leipzig are equal—with about 700 in each university. Besides, I am more conversant with the conditions in the last two named from a residence at each.

The two greatest of the Scottish schools have always complained of a lack of accommodation, although, sixteen years ago Glasgow became possessed of its magnificent new pile, with its greatly enlarged class-rooms, and Edinburgh, still more recently, of the most spacious rooms and laboratories in the United Kingdom.

The growth of the German universities, especially of Berlin and Leipzig, since the close of the Franco-Prussian war, has taken place very rapidly; and now, in Leipzig, the Zootomical Institute is possessed of three laboratories and as many lecture rooms, besides a splendid museum and a series of workrooms. In Glasgow, unfortunately, it is impossible to find room in the museum for the exhibition of the unrivalled collection of Hunter's dissections, most of which are confined to an upper room. It is unfortunate that the University cannot supply room for exhibiting the whole of this magnificent collection which, together with the accumulations since, exceed in value a quarter of a million sterling. But the disparity in the space allotted to each is greatly accentuated when we consider the staff which Leipzig and Glasgow respectively possess. In Leipzig, the Zootomical Institute is presided over by a Director, who is also Professor Ordinarius of Zoology and Zootomy. Besides the ordinary professor, who lectures during one semester on Comparative Anatomy, and on General Zoology during the other, in the semester of 1886-7 it had a Professor Extraordinarius of Comparative Embryology, who demonstrated and lectured on Vertebrate Embryology, and also delivered a course of lectures on the Descent of Man; a second Professor Extraordinarius, who selected for treatment the special anatomy of half of the Vertebrata, and also delivered two lectures weekly on the Darwinian Theory; a *Docent*, since promoted to be a Professor Extraordinarius, who lectured on Embryology and conducted a practical course of Comparative Histology. Besides these, the following also were engaged in teaching in the University:—A Professor Extraordinarius, who lectured on the Anatomy of the Domestic Animals, on theories of Animal Breeding. and also on the Geographical Distribution of Animals; and a *Privat Docent* who dealt with the Palæontology of the Invertebrates.

Setting these forth in tabulated form, we have, therefore, the following equipment for the winter's Zoological work:—

1. Professor Ordinarius,	Comparative Anatomy,	Lectures 6 Hours Weekly.
	Zoological and Zootomical Laboratory, with Assistant.	Practical 6 Days.
2. Professor Extraordinarius,	Comparative Embryology,	Practical 6 Hours Weekly.
	Descent of Man, II.,	Lectures 1 ,, ,,
3. Professor Extraordinarius,	Special Zoology of Vertebrates,	Lectures 5 ,, ,,
	Darwinian Theory,	Lectures 2 ,, ,,
4. Professor Extraordinarius,	Embryology,	Lectures 2 ,, ,,
	Comparative Histology,	Practical 6-9 ,, ,,
5. Professor Extraordinarius,	Anatomy and Physiology of Domestic Animals,	Lectures 4 ,, ,,
	Geographical Distribution of Animals,	Lectures 2 ,, ,,
	Theories of Animal Breeding,	Lectures 2 ,, ,,
6. *Privat Docent*,	Palæontology of Invertebrates,	Lectures 3 ,, ,,

In addition to the above facilities for the study of Zoology, we have in the Anatomical Institute two Professors (Ordinary) and one *Docent* who teaches Histology; in the Physiological Institute two Professors and two *Docents* who teach Physiology, Physiological Chemistry, and Histology; and in the Botanical Institute four teachers who deal with Morphological and Physiological Botany.

If we contrast the zoological equipment of Leipzig with that of Glasgow, we find that against the five professors, one *docent*, and one assistant, we have a staff of one professor and one demonstrator or assistant. The professor is compelled also to teach geology, and to superintend the magnificent collection of zoological and geological specimens, and be a constant source of reference on numismatic and bibliographic matters.

But, over and above, the whole equipment is provided by the University of Leipzig, which is very liberally subsidised by Government, receiving the sum of £40,000—more than the four Scottish Universities taken together receive from the National Exchequer. In Leipzig the material for use—instruments, microtomes, microscopes, incubators, and tanks—is provided by the University, while in Glasgow the professor, whose salary does not equal the German ordinary professor, furnishes all such himself.

As a consequence of the splendid facilities afforded for instruction in such a great number of subjects, some of which are not taught in any of our universities, it need not surprise us that British, American, and Russian students, and others from the Balkan provinces, when they desire to study the higher branches of science, migrate to some German university where there is some likelihood of having their wishes gratified. In no British university, so far

as I know, can you find representatives of so many nationalities as you will meet with at a German university. The Americans, perhaps, more than any other foreign nation, take advantage of the opportunities open to them, and it does not require much insight into their college system to trace how they have profited by their German residence.

As in other countries, so in Germany, the work carried on by the students is with a view to a degree. The German student enters his university in a fitter state to profit by the instruction there. Not only does his study in the *Gymnasium* and *Realschule* last for a greater number of years than does that of an academy boy in Scotland, but it is carried to a still higher standard than in the case of a boy preparing for the university in this country. To prevent the entrance of too raw material into the precincts of the university the German has to produce his *Abgangs-Zeugniss* from the secondary school. As a general rule, the German does not enter the university till he has attained at least eighteen years of age. The degree of Ph.D. is open to biological students in the department of natural science. The length of time spent within the university previous to obtaining this honour is generally three years, and during that period a student's time is devoted to the study of one subject —a major—in which he is expected to make some solid contribution to a knowledge of the science. He must write a thesis embodying the results of his investigation preparatory to his oral examination in the same subject. Besides, he must undergo an oral examination in two minors. In natural science he can take any three of the following:—zoology, mineralogy (including geology), chemistry, physics, botany. He selects one as major and any other two as minors. In the whole course specialization is carried out. But specialization in the case of the German student is not so hurtful as it would be in the case of the student in a Scottish university, as the latter is not nearly so well equipped at the commencement of his university course as the German. In consequence of this specialization under the fostering care of such a large staff as exists in the different institutes of the universities, the Germans lead the world in scientific knowledge. From the laboratory of Leipzig alone has come the greater share of our knowledge of the life-history of most of our *Entozoa*. Of the additions which this university has made to our knowledge of the bladder and tape-worms, and of such diseases as trichinosis, the Germans may well feel proud. But the work of the laboratory is helped by the

connection which subsists between the different German states and such marine stations as the magnificently-equipped one at Naples. Naples Marine Biological Station, where work is carried on both in morphology and physiology, is chiefly supported by Germany and Italy. The German graduate who wishes to further his work in zoology may go to Naples; or, if he be a student of Vienna University, the marine station at Trieste, which is associated with this university, presents great inducements and opportunities for work.

In Britain, the new station at Plymouth should be of great assistance to the science of zoology. In Scotland we have already a few—one at Granton, connected with the Meteorological Society—one at Rothesay, connected with the Fishery Board; and an attempt is being made to start one in the Hebrides at Loch Buie, in Mull. In all our Scottish stations the complaint is as to the lack of funds to support them. When we, however, view the work which such marine stations are accomplishing for the Fisheries Commission of the United States, we may well envy the considerate manner in which the Government there treats its scientific departments.

In this country there is a vast field awaiting inquiry, the problems of which can only be solved by the aid of the Government. We have such questions regarding the life-histories of our fishes, as the conditions determining the presence of fish on our coasts, how these are dependent on temperature, current, amount of sea-weed, and number of molluscan and crustacean larvæ affording food to the fishes.

All these questions are bound up together and are interdependent on one another. In our fisheries we require trained assistants who would be helpful to them as the chemist is to the manufactory. We cannot expect to rear such unless something like equal opportunities are given to the Scottish student of zoology as the German already possesses. What is wanted in the Scottish universities is not so much increased accommodation—though this is to be greatly desired—as an increase in the teaching staff. Everything in biology is sacrificed to the medical, and too little encouragement is given to the student of science. If we are to keep pace with the times we live in, and assist in solving the questions regarding disease and food supply which are being forced on the attention of biologists, it behoves us not to view with calm indifference the comparative neglect of the claims which Biological Science is making upon us.

XXX.—*On the Physical Conditions of the Water in the Clyde Sea-Area.* By Hugh Robert Mill, D.Sc., F.R.S.E., F.C.S., of the Scottish Marine Station.

[Read before the Society, 16th February, 1887.]

In a paper* read before this Society on 31st March, 1886, Mr. John Murray discussed the temperature conditions of the eastern part of the North Atlantic, and took occasion to point out that we were in almost complete ignorance as to the annual changes of sea temperature in the channels and deep lochs connected with the Firth of Clyde. Struck by the great importance of an exact knowledge of these conditions, Mr. Murray, as Director of the Scottish Marine Station, organised and personally superintended a series of cruises at various seasons, in the course of which numerous observations were made. The results of these cruises in a general form are embodied, so far as temperature is concerned, in the present paper. It was my good fortune to take part in nearly all the work to be described, and we were assisted also on several trips by Mr. J. T. Morrison, and on one by Mr. H. N. Dickson.

Observations on the temperature of enclosed and partially enclosed seas in Northern Europe have been made by many investigators. The principal work has been done on the Baltic and North Sea by the German Government and the Governments of the Scandinavian nations.† Reference may also be made to the work of the British Government and the Norwegians in the Færöe Channel‡ and North Atlantic,§ to the observations on estuaries

* "On the Physical and Biological Conditions of the Seas and Estuaries about North Britain."

† See the publications of the Commission in Kiel for exploring the German Seas, the report of the voyage of the *Pommerania* in 1872, and that of the *Drache* in 1882-84, published by the German Government. Also Ekman's Hydrographic Investigations, published in Sweden.

‡ Thomson's Depths of the Sea, 1871. Work of the *Knight Errant* and *Triton*, *Proc.* R.S.E., 1881-82.

§ *Publications* of Norwegian North Sea Expedition, Christiania.

carried on by the Scottish Marine Station;* and to the observations on Loch Lomond and other deep Scottish lakes, which were commenced long ago by Christison, and have since been carried on systematically for some years by Mr. J. Y. Buchanan,† with the assistance latterly of Mr. Morrison and myself. The conditions of fresh-water lakes differ from those in sea lochs, chiefly on account of the greater density of sea water, and the tidal influences in the latter, and because of the phenomena of the maximum density point of fresh water.

An exhaustive treatment of the "Physical Conditions of the Water in the Clyde Sea-Area," requires at least six different branches of investigation. These may be indicated as follow:—

1. Configuration, and geological conditions of the area.
2. Salinity and chemical composition of the water at different places and at various depths.
3. Volume, velocity, and temperature of all the rivers entering the sea-area; and the seasonal variation of these.
4. General meteorology—Rainfall, prevailing winds, temperature of air, total sunshine.
5. The tides—Direction and velocity of tidal currents and amount of rise and fall.
6. Temperature of the water at all depths, in all parts of the area, and at all times of year.

Once these data were ascertained, the amount, source, and destination of all the heat involved in summer and winter changes could be accurately determined, and a full discussion of the "physical condition" of the water in the widest sense would be possible. Then we would be in a position to apply our knowledge to questions of biology, climatology, &c., and through these to more practical matters connected with arts and industries. So far as we have yet gone, only the last-mentioned research is in a position to warrant discussion. The salinity and chemical composition of the water are being investigated by the staff of the Marine Station, and in greater detail by Mr. Dickie in Professor Dittmar's laboratory. The data of Nos. 1, 4, and 5, may be gathered, though not with satisfactory completeness, from the records of the Admiralty in its Hydrographic Department, the Geological Survey, and the Scottish Meteorological Society. No. 3, the

* Mill, *Proc.* R.S.E., vol. xiii. *passim*: *Scot. Geog. Mag.*, ii., 1886, pp. 20-26.

† *Proc.* R.S.E., vol. xiii., 1886, pp. 403-428.

investigation of rivers, has never been undertaken, and to inaugurate a work of such magnitude as this would be is too much for the present resources of the Marine Station.

For particulars as to the configuration of the Clyde Sea-Area, and for a coloured bathy-orographical map, reference must be made to a special paper, * but a brief enumeration of its chief features is necessary. The deep water of the North Channel and St. George's Channel shoals rapidly from 70 to 27 fathoms, the latter depth being the average over a wide *Plateau*, 270 square miles in area, that runs from Cantyre to Ayrshire, touching the south coast of Arran, and including Ailsa Craig. The shallowest ridge of this plateau is about 20 fathoms deep. Along the Ayrshire coast the water continues shallow, but on both sides of Arran there are deep channels uniting at the north end of that island, and continuing up lower Loch Fyne almost to Ardrishaig. This λ-shaped system is known as the *Arran Basin*. Its maximum depth (107 fathoms) occurs off Skate Island, near Tarbert, in lower Loch Fyne, and the areas of water at each depth may be seen from the following table :—

Depth exceeds	30	fathoms	over	340	square	miles.
,,	,,	50	,,	,,	100	,,	,,
,,	,,	80	,,	,,	10	,,	,,

The *Bute Plateau* separates the Arran Basin from the Dunoon Basin and Loch Striven; its average depth is about 20 fathoms. *Dunoon Basin* extends from a little north of Great Cumbrae through the Firth of Clyde and up lower Loch Long to the Dog Rock, off the mouth of Loch Goil; its greatest depth is 56 fathoms off Dunoon. The *Estuary* from Greenock to Bowling is extremely shallow, and partakes largely of the nature of a canal. The *Gareloch*, 5 square miles in area, has an average depth along the central line of 20 fathoms. *Upper Loch Long*, with an area of 4 square miles, has a maximum depth of 35 fathoms; and *Loch Goil*, with the same superficial extent, descends to 47 fathoms at its deepest point. *Loch Striven* covers 5 square miles, and has as maximum depth, 35 fathoms. *Upper Loch Fyne* (from Otter Ferry) is 25 miles long, and measures 20 square miles superficially. There is a shallow depression (Minard Basin) between the two ridges rising to within 15 fathoms of the surface at Otter and Minard, and beyond Minard Narrows the depth goes down to 80

* Scottish Geographical Magazine, vol. iii., p. 15, Jan., 1887.

fathoms off Strachur. The separation of Loch Goil from the Dunoon Basin is by a barrier steeper on both sides, and rising nearer the surface, within 10 fathoms. The four lochs last-named are enclosed by high, and in many cases, by precipitous hills; the most closely invested by mountain walls is Loch Goil, and next to it come the upper six miles of Loch Fyne and Loch Long. Smaller natural divisions need only be mentioned: the principal ones are the Holy Loch, Kyles of Bute, Loch Ridden, Loch Shira, Loch Gair, Loch Gilp, East Loch Tarbert, Campbeltown Loch, Loch Ranza, and Lamlash Bay.

Taking the boundary line of the sea-area as the contour of 50 fathoms, which runs from the Mull of Cantyre to Corsewall Point, its entire area is 1,300 square miles, thus divided :—

Depths between	0	and	10	fathoms,	105 square miles.
,,	,,	10 ,,	30	,,	635 ,,
,,	,,	30 ,,	50	,,	450 ,,
,,	,,	50 ,,	80	,,	100 ,,
,,	over 80 fathoms				10 ,,

For the purposes of the present paper it will be advisable to consider most particularly the thousand square miles lying northward of the ridge of the Barrier Plateau. Of this region the following table gives particulars:—

	Depth in fathoms.	Mean Depth.	Area in square statute miles.	Volume in square-mile fathoms.
	0 to 10	5	100	500
	10 ,, 30	20	440	8,800
	30 ,, 50	40	350	14,000
	50 ,, 80	65	100	6,500
	Over 80	87	10	870
Total,	0 to 107	30·67	1,000	30,670
Tidal rise,	1 to 2	1·5	1,000	1,500

In larger units the 1,000 square miles of area have a mean depth of 30·67 fathoms at low tide, and consequently a volume of water equal to 34·87 cubic miles; while at high tide there is 1·7 cubic mile more water in the system. Taking the average density of the water as 1·025, which is probably rather under the mark, 1 cubic mile of it would weigh 4,203,030,000 tons; hence, the total weight of water at low tide inside the Plateau is 146,560,000,000 tons, and that of the tidal increment, 7,145,300,000

tons. Or, to use round numbers, at the mean state of the tide there are 150,000 million tons of water in the system. For the data on which these calculations are based I am indebted to the planimeter measurements by Mr. Chumley, of the *Challenger* Office, on Mr. J. G. Bartholomew's bathy-orographical map of the Clyde sea-area.

Methods of Working—Thermometers.

Mr. Buchanan's improved Miller-Casella thermometers were used to a slight extent on one or two trips, but the instrument chiefly, and latterly exclusively, employed was Messrs. Negretti & Zambra's Patent Standard Deep-Sea Thermometer. This thermometer registers the temperature by being caused to turn over; in the act of turning, the mercury column breaks at a contraction near the bulb, runs down into what was the upper part of the tube, and remains there until the instrument is set again. The tube is graduated in the inverse position, so that the temperature is read off directly. The instrument is graduated to read correctly at the temperature at which it was reversed; hence a correction demanded by the change of volume of the detached column becomes necessary when the reading is made at a different temperature from that of reversal. This correction, as the average of eight instruments, was found to be 0°·1 for 6° F. change of temperature. This is so slight as to be readily overlooked, because when there is more than 6° difference between the temperature of water and that of the wet-bulb thermometer in air, the reversing thermometer is read before it has time to assume its new temperature, and if a strong wind quickly brings it into equilibrium with the air, the motion of the vessel is such as to render it difficult to read to tenths of a degree. In all ordinary states of weather it has been found possible to rely upon the readings of temperature as correct to one-tenth of a degree Fahrenheit.

The arrangement employed for reversing the thermometer is known as the "Scottish frame." It acts by the fall of a brass "messenger" along the line depressing a lever, and so raising the pin that retains the thermometer in an upright position. Any number may be used on one line—the "messenger" intended to reverse the next lower instrument being hung by a cord or wire, so as to be set free on the thermometer turning over. A special vice-clamp enables the thermometer to be attached to the line and *removed* with great rapidity; and it has also the advantage over

lashings that the observer can employ it even when his hands are benumbed. The Negretti & Zambra thermometers have an outer protecting sheath to keep off pressure from the bulb, and as the only liquid in their construction is mercury, they rapidly assume the temperature of the water. An immersion of three minutes is in all cases sufficient.

A slip water-bottle is employed for raising samples of water from any desired depth. It is closed by a "messenger" dropped by the lowest thermometer on its reversal, and can thus be employed on the same line as the thermometers.

The small steam yacht of the station, the *Medusa*, was specially built and fitted for sounding and dredging in quiet water. She is of 30 tons yacht measurement, and about 54 feet long on deck. Her small size makes it easy to keep position without anchoring, while making observations, but the corresponding disadvantage is associated with it of being unable to work in rough weather—except in the narrow lochs and channels. When the bearings of an observing station have been reached the vessel is put head to sea, with the wind on the port bow, and one man keeps her in position, the engines and steering wheel being both worked from the same place—amidships. The sounding line, of 120 fathoms, is coiled on a drum, and worked by a small donkey engine. The line passes from the drum, through leading-blocks, to a tail-block hung from the end of a derrick, which projects over the port bow. The line is marked with worsted at every fathom, for the first ten, then at every five fathoms to the end, the tens being in red, and having a number of turns corresponding to the depth, the fives a single tuft of blue. The water-bottle and lead are always attached to the line, a thermometer is clamped on above the open bottle, and a "messenger" hung to it to reverse the latter. Ten fathoms are allowed to run out, the second thermometer and "messenger" are fixed, and at the end of other ten fathoms the third instrument is attached, and the line allowed to run until the lead strikes bottom. The depth is noted in an observation book, in which particulars as to position, date, hour, weather, wind, temperature of air, and height of barometer are recorded. Air temperature is observed by means of a small thermometer (*thermomètre fronde*) whirled by a cord so as to take the temperature of the air rapidly; after observing this the bulb is dipped in water, and the thermometer swung again for the wet-bulb reading. Three minutes or more having elapsed, a "messenger" is allowed to slip down the line; it

strikes the first thermometer, reverses it, and sets the second "messenger" off on its course. When the shocks of the reversal of all the thermometers, and the closing of the water-bottle, have been felt (this cannot be done when there is any sea on; then a sufficiently long time interval must be allowed), the line is rapidly run in by the donkey engine, and each thermometer removed, read, and its temperature recorded as it comes up. The process is repeated until the temperature has been ascertained at the surface, 5 fathoms, 10 fathoms, and every ten to the bottom. The recorded readings are examined, and if any sudden change is noticed between any two of them additional observations are made at intermediate depths, until a fair idea of the vertical distribution of temperature is arrived at. A sample of surface water is collected, and the vessel proceeds to the next station; while, unless there is too much motion, the density of the water samples is being ascertained by means of the hydrometer. The curve of vertical distribution is drawn from the figures in the observing book after the instrumental corrections have been applied, and from the curves isothermals are laid down on a profile of the sea bottom, so as to guide the observations at next station. Thanks to the rapid working of the Negretti & Zambra thermometers, and to the convenient fittings of the *Medusa*, and the dexterity of her crew, a stoppage of fifteen minutes suffices to ascertain the temperature at nine points, and one of twenty-five minutes at fifteen points when the weather is fine. Using the same number of thermometers (three), the *Challenger* type instruments would require stoppages of from one hour to an hour and a-half for the same amount of work.

At intervals of six weeks or two months a complete tour of the Clyde Sea-Area is made in the *Medusa*, the time occupied being from seven to ten days, according to the time of year and the weather. Soundings are taken as nearly as possible at the same positions, but occasionally it is necessary to make more numerous observations, in order to trace out special distributions of temperature. The following are the positions and the approximate depths in fathoms where observations are regularly made:—

In the *Estuary*—

In mid-channel, off Bowling (3).
" Dumbarton (3).
" Port-Glasgow (3).
" Greenock (15).

In the *Dunoon Basin*—

Off Dog Rock, opposite Loch Goil (50).
Between Coulport and Ardentinny (42).
Off Strone Point (30).
South of Gantock Beacon, Dunoon (50).
Off Wemyss Point (40).
Off Knock Hill (40).

On *Bute Plateau*—

Rothesay Bay (9).
Between Toward and Bogany Points (27).
Off Ascog (23).

In *Arran Basin*—

Between Garroch Head and Cumbrae Light (60).
5½ miles off Brodick (90).
2 miles off Largybeg Point (60).
Between Imacher Point and Carradale (75).
Off Areverga Point (70).
Off Loch Ranza (50).
Midway between Arran and Inchmarnock (85).
Midway between Ardlamont Point and Ettrick Bay (30).
Off Skate Island (107).
Off Kilfinan Bay (55).
West of Otter Beacon (30).

On *Barrier Plateau*—

Off Davaar Island (18).
East of Sanda Island (28).
South of Pladda Island (20).
Near Ailsa Craig (27).

In *North Channel*—

Two positions as far off shore as the weather permits, and in from 40 to 70 fathoms.

In *Gareloch*—

Off Helensburgh Pier (6).
Seaward of Row Point (12).
Inside Row Point (23).
Off Shandon (21).
Garelochhead (10).

In *Holy Loch*—

Between Strone Point and Hunter's Quay (16).
Between Kilmun and Sandbank (10).

In *Upper Loch Long*—

Off Thornbank (35).
Off Arrochar Pier (10).

In *Loch Goil*—

Entrance (8).
Off Stuckbeg (40).
Off Lochgoilhead Pier (27).

In *Loch Striven*—

Between Strone and Ardine Points (33).
Off Clapochlar Point (35).
Head of Loch (12).

In *Kyles of Bute*—

Off Strone Cotes (20).
Burnt Islands (25).
Off Ormidale Pier, Loch Ridden (12).

In *Loch Fyne*—

East of Otter Beacon (20).
Off mouth of Loch Gair and Gortans Point (30).
In Minard Narrows (15).
Off Furnace Quarries (35).
Off Strachur (75).
Off Inveraray (60).
Off Dunderave (30).
Off Cuill, head of Loch (15).

Occasional soundings are also taken in Loch Gilp, Loch Ranza, Campbeltown Loch, Lamlash Bay, and Millport Bay. There are thus more than sixty places where observations are made. It is not considered necessary to give exact bearings of each, especially as in most cases the channels are so narrow that a position of the depth mentioned is defined to a few hundred yards by the description "Off" such a place.

Treatment of Results.

It is impossible at the present stage of the investigation to give an exhaustive discussion of all the observations which have been

made. With a large number of new facts of any kind it is difficult so to group them as to bring out all that may be legitimately deduced from their consideration. Accordingly, until there has been time to compare all the data in various ways, I think it better to deal with the matter in as general a manner as the nature of the circumstances permits, and to employ graphical methods rather than numerical for that purpose.

Until the introduction of thermometers which registered the exact temperature at a given depth, and not merely the maximum and minimum temperatures through which they passed, it was assumed that the temperature of water varied uniformly from surface to bottom, except when the surface was frozen. Consequently it was the custom to draw a free-hand curve through points obtained at a considerable distance apart, and to view this curve as a representation of the manner in which temperature varied. This is now recognised to be erroneous, and our observations on the Clyde Lochs show that, within certain limits, the temperature of water may vary in any manner between the surface and the bottom. Hence the greatest caution must be exercised in interpreting curves, and at all places where the direction or the amount of curvature is changing, very close observations must be made. This fact was not sufficiently realised during the first two or three cruises to be described, but each trip suggested new precautions, and, consequently, the later results are the more trustworthy.

RESULTS.

The seasonal changes of temperature in three characteristic regions will be described in some detail. It has been found that the physical configuration of the sea-bottom exercises a most important influence on the temperature of the water, and the three positions hereafter cited are types of three different conditions tending to limit more and more the free circulation of the water.

The *Channel* near the Mull of Cantyre could only be examined on five trips, and water over 50 fathoms was only reached twice—first, on April 16, an exceptionally calm and fine day, and again on September 22nd, when Mr. Matheson of Liverpool kindly gave the use of his large steam yacht, the *Oimara*. On every trip the same temperature was found to prevail practically from surface to bottom. Occasionally patches of rather warmer water were found on the surface, with the ebbing tide, but these were neither large nor deep. The curves of vertical distribution of

temperature for this region (Fig. 1) are nearly straight lines, and more parallel to themselves throughout as the season changes.

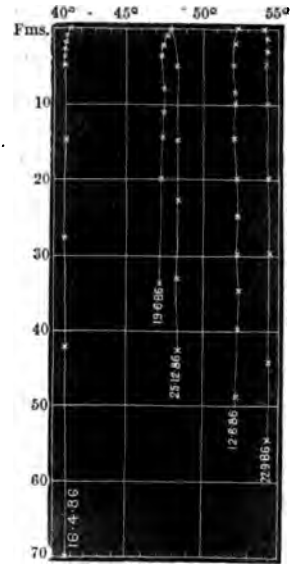


Fig. 1. Temperature Curves for Channel.

In summer the surface was sometimes the fraction of a degree higher, in winter sometimes the fraction of a degree lower in temperature than the mass of the water. The actual figures are:—

April 16.	June 19.	Aug. 12.	Sept. 22.	Dec. 25.
42·0	47·4	52·5	54·5	48·5

The maximum thus appeared to be in September, the minimum in April, and the whole observed range was 12°·5.

The Channel is characterised by very strong tidal currents, and by the occurrence of overfalls or tumultuous mixing of the water throughout its whole depth, as the tide sweeps over sudden inequalities on the bottom. It is in perfectly free connection with the Atlantic, and consequently is affected by the Gulf Stream water.

The deepest water of the *Arran Basin* is affected by the tide which passes over the Barrier Plateau, and thus reaches the deep, beyond as a moving layer, certainly not over 20 fathoms deep; but this surface flow appears to set up a deeper circulation, and *to change* all the water in the deepest hollows in the course of time.

The observations here are very complete, as the following statement and the curves (Fig. 2) expressing it show :—

	Mar. 27.	April 19.	June 21.	Aug. 10.	Sep. 17.	Sep. 26.	Nov. 16.	Dec. 29.	Feb. 7.
Surf., ...	41·4	43·8	48·3	53·6	54·7	53·9	49·3	46·6	43·7
Bot., ...	41·5	41·3	44·0	45·6	47·4	47·4	51·1	47·4	44·3

Here the surface range was 13°·3, the minimum occurred in March and the maximum about the middle of September. At the bottom the range was 9°·8, with a minimum in April and maximum in November. In March the curve of vertical distribution was identical in form with that for the Channel;

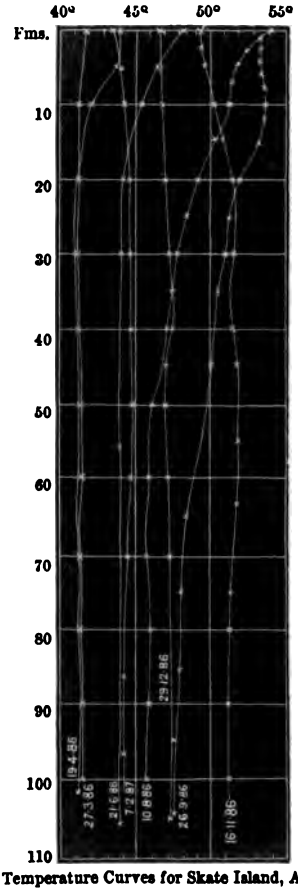


Fig. 2. Temperature Curves for Skate Island, Arran Basin.

from March to August the lower layers heated up uniformly, and from November to February they cooled down uniformly as the

curves evidence by parallel and perpendicular lines. The mass which thus heated and cooled uniformly was less and less every month until November, when there was none, and then at one leap nearly the whole body of water assumed this state. The meaning of this is that the advance of summer poured heat into the surface layers more rapidly than it could be conducted downwards, either by the process of conduction proper or by convection, while, on the other hand, the cold of winter withdrew heat from the upper layers more rapidly than conduction or convection could equalise the supply from the mass. Only in winter cooling *en masse* is much more rapid because, as Aimé long ago pointed out, cooled water sinks, carrying down cold so to speak, while heated water remains floating. It would appear as if the lower mass of water, which was uniformly heated as summer advanced, was influenced by the direct mixture by uniform descent of the hotter and salter tidal water coming across the plateau and streaming northward over the surface. It is interesting to note the extreme similarity of the curves for June and for February. The one seems to be almost a mirror image of the other; the temperature for the lower 91 fathoms was on the average just half a degree warmer in February than in June, at 15 fathoms it was the same (44°·3), while on the surface in June it was 48°·3, and in February 43°·7, the greater difference between surface and 15 fathoms deep in summer being due to the reason stated above. A few slight irregularities will be observed in the curves—thus, that for February has its maximum (45°·0) at 45 fathoms. This is not a result of error of observation, but the next set of soundings illustrates the same effect much better.

At *Strachur*, in Upper Loch Fyne, the influence of the tidal flow is very slight, except on the surface. The currents are successively checked by the narrow and shallow channels at Otter and Minard, and so they reach the wider upper reaches without strength to effect any mixture at the great depth of 70 fathoms, or more. As the conditions in the Arran Basin were shown to differ markedly from those in the open channel, so—and even to a greater degree—do the conditions in Upper Loch Fyne differ from those in the Arran Basin. The temperature observed at surface and bottom for the several months was as follows:—

	Apr. 20.	June 21.	Aug. 11.	Aug. 25.	Sept. 27.	Nov. 17.	Dec. 29.	Feb. 4.
Surf.,	42·6	49·2	54·1	53·5	52·4	46·4	41·0	43·0
Bot.,	41·9	44·1	44·2	44·2	44·1	44·2	44·7	45·9

These figures show a very curious state of matters: while the surface water rose from 42°·6 in temperature to 54°·1 in four months, and fell to 41° in three, the bottom rose only from 41°·9 to 44°·1 in two months, and for five months remained practically unchanged, then rose in two months and a-half to 45°·8. Thus the surface water had a range of 14°·1 in warmth, the bottom water only 4°; and the surface maximum occurred in August, while the bottom had apparently not yet reached its maximum in February.

The remarkable state of matters in this loch is made much more evident by considering the curves of Figure 3, which show

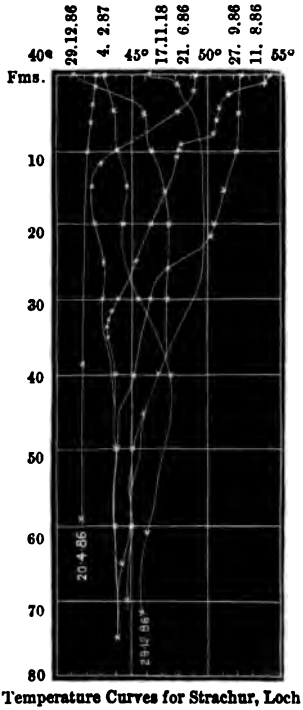


Fig 3. Temperature Curves for Strachur, Loch Fyne.

the vertical distribution of temperature for each trip. The curve for April is practically straight, and shows a uniform distribution of temperature from a depth of 15 fathoms to the bottom; but, unfortunately, very few observations were made, and it is possible that a sub-surface maximum or minimum may have been missed. In all the others from ten to twenty points were determined. By June the bottom water had warmed up to 44°·1, but the lowest

temperature occurred at 15 fathoms, where it was 42°·5, from that point warmth rapidly increased to the surface. The lower 40 fathoms of water remained practically unchanged at the temperature of 44°·2 until the end of August, but the warming towards the surface went on more and more rapidly. In September the lower 25 fathoms retained the old temperature; there was a rapid rise of temperature toward the surface until, at 10 fathoms, it became constant at 52°·5. In November the temperature at the bottom was still unchanged, but it rose rapidly from the bottom until within 30 fathoms of the surface, continued to rise very gradually to within 10 fathoms (50°·0), and then commenced to fall, reaching 46°·4 on the surface. In December the greatest depth had warmed up a little, the temperature attained a maximum (47°·5) at 20 fathoms from the surface, then fell at first slowly, finally very rapidly, for the extreme superficial layer consisted of ice, the frozen fresh water which had run down, after a sudden thaw, from the hills and spread itself over the surface of the salt water. By February there was considerable increase of temperature at the bottom (45°·9), and, after passing an ill-defined maximum of 46°·5 at 45 fathoms, it fell very uniformly to 43°·0 on the surface. It is almost certain that before another trip is made the maximum temperature will have reached the bottom, and cooling will have set in throughout. This set of curves is similar to that obtained in the similar rock basin of Loch Goil. It is very instructive, as showing how the heat wave is propagated downwards with diminishing amplitude as the season advances, and how the succeeding cold wave travels after it. No conclusions can yet be drawn from these data as to the seasonal march of temperature in Loch Fyne, as the cycle of annual change has not yet been completely observed.

Figure 4 represents the changes in surface and bottom temperature with the season, so far as observations go, at each of the three stations that have been considered. The curve for the Channel may be taken as the standard to which the others are referred. The surface curves all rise together, that for Strachur comes soonest to a maximum; after passing the maximum the Channel curve continues highest. The bottom curves rise more slowly, ultimately cross the surface ones, and come to a maximum much later. The curves for the Skate Island depression of the Arran Basin are in all cases intermediate between those of the *Channel* and Strachur.

The three cases just considered are all deep-water stations. The changes in shallow lochs and channels are less regular, they

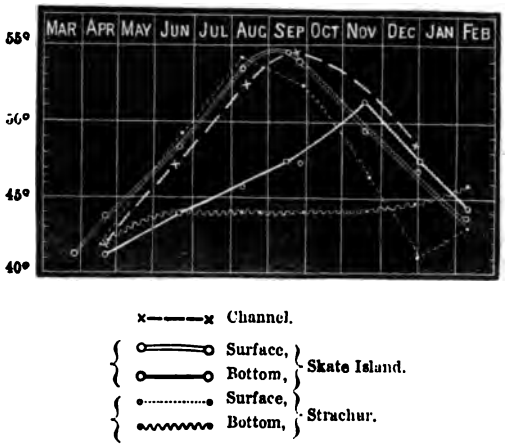


Fig. 4. Seasonal Variations of Temperature.

respond more rapidly to the changes of air temperature, but in all essential respects they are similar to those discussed, and it is not necessary to consider in detail the fifty-seven other stations for which data have been collected.

In order to combine in some manner the information regarding the most important stations, a series of temperature sections was constructed for each cruise. The two principal sections ran from the Channel in the one case up Kilbrannan Sound and Loch Fyne, in the other up the east side of Arran to Loch Goil. Both these sections are extremely characteristic. That including Loch Goil deals with shallower water, and consequently shows a greater range of temperature, and a more obvious following of the variations of air temperature, but the other is on the whole more interesting, and will be described.

The profile shown in the diagrams (Plate XI.) was constructed from the Admiralty charts, and in order to show the vertical distribution of temperature the depth is greatly exaggerated compared with the length. A line is drawn to represent each sounding, and the depth at which each whole degree (in some cases each half degree) of temperature is reached, as indicated by the station curves, is marked, and isotherms are drawn accordingly. In order to appeal to the eye the spaces between the isotherms are

coloured in the order of a spectrum, the highest temperature being shown as red. Thus, below 40°, is shown as violet :—

From 40° to 42°, - - - - -	blue.
,, 42° to 44°, - - - - -	greenish blue.
,, 44° to 46°, - - - - -	bluish green.
,, 46° to 48°, - - - - -	green.
,, 48° to 50°, - - - - -	yellow.
,, 50° to 52°, - - - - -	orange
,, 52° to 54°, - - - - -	red.
Above 54°, - - - - - -	deep red.

The April section shows a very simple state of matters. The whole area is blue, the temperature lying between 41°·3 and 44°, and with the exception of about 10 fathoms of water nearest the surface, which is coloured on greenish blue (over 43°), it is of one colour. This may be taken as the typical distribution of temperature in very early spring, before the winter conditions have been seriously disturbed. It was the period of minimum temperature over the whole sea-area as far as we have been able to ascertain.

The lapse of two months of spring and summer weather brings about a considerable change by June, as the section for that month shows. Sun-heating has produced tracts of warm water on the surface, here and there the yellow colour (48° to 52°) descending in some cases to over two fathoms. The Channel and Plateau are green (46° to 48°), and water at this temperature is found on the surface in a thinner and thinner layer as far as Otter, and appears again to a depth of about eight fathoms in Upper Loch Fyne. Water at from 44° to 46° (bluish green) fills the bulk of the Arran Basin, the Minard Basin, and the lower part of Loch Fyne. But the centre of Loch Fyne remains blue as it was in April, a mass of water from 42° to 44° floating between the warmer layers. This singular condition has not yet received a satisfactory explanation. This section represents the condition of rapid heating in early summer.

The August section, not reproduced here, shows a great advance. The Channel and Plateau are red (over 52°), and all the surface water except at Otter. Yellow (48° to 52°) extends from the end of the red to a depth of 30 fathoms in the Arran Basin, fills the Minard Basin, and extends down to from 5 to 15 fathoms in Loch Fyne. The remainder of the Arran Basin and Loch Fyne are green (44° to 48°), except for a small remnant of the greenish blue layer (under 44°) in Upper Loch Fyne.

The September section, representing the period of maximum temperature, is the natural contrast to that for April. It is typical of the end of summer. The Channel, Plateau, and surface water are red (over 52°), and the upper and outer layers dark red (over 54°). Yellow (48° to 52°) extends to 25 fathoms in Loch Fyne, fills the Minard Basin and the Arran Basin down to 75 fathoms, where green (47°·5) comes in. The bottom of Loch Fyne is bluish green, and now contains the coldest water in the system.

In the section for November are shown the autumnal conditions established and passing into the wintry. Surface-cooling has reduced the temperature below 52°, and the red is gone; but, except in Loch Fyne, warming has proceeded until all green is gone, and the whole area lies between the temperature of 48° and 52°. The Channel (by assumption, for no observations were made in it), Plateau and Arran and Minard Basins are over 50°, except that north of the Plateau the surface is for seven fathoms considerably cooler (yellow). In Loch Fyne there are four layers of ten fathoms each, respectively—yellow (48° to 50°), orange (50° to 52°), yellow (48° to 50°), and green (46° to 48°); below 50 fathoms it is bluish green (44° to 46°).

In December cooling had continued, yellow remained in the Channel, but the Plateau and all the Arran and Minard Basins were green (46° to 48°), except on the surface, where bluish green (44° to 46°) appears, and sinks to 10 fathoms at the head of Loch Fyne, where the old bluish green persists below 50 fathoms.

The February section may be viewed as that of early winter in the water, the autumnal conditions have fairly disappeared, and the diagram is blue and green, as in June. The Channel, presumably, and the Plateau, certainly, are greenish blue (42° to 44°), extending to Imacher, and passing by almost vertical transition into bluish green (44° to 46°), which fills the Arran and Minard Basins to within five fathoms of the surface, while the blue (40° to 44°) and in places a film of violet make up the rest. Loch Fyne is blue (40° to 44°) to eight fathoms, bluish green (44° to 46°) to 34 fathoms, green (46° to 46°·5) to 60 fathoms, and the old bluish green (45°·8) thence to the bottom.*

* The colours refer to those on the four diagrams (Plate XI.), and not to the natural tint of the water, which is unaffected by temperature.

The general impression created by examining these sections is that heating proceeds from the surface downwards, and from the sea inwards. The deep basins, which are cut off by barriers from complete circulation, retain a low temperature during summer longer than the more open regions, while they gradually acquire a higher temperature in their deeper layers during winter. The shallow Minard Basin was always found to be filled with water of the temperature of that outside at the plane to which the summit of the barrier reaches. It is noticeable that at Otter, where the Arran Basin terminates, the surface temperature is always considerably lower in summer, and usually a little higher in winter than that in the neighbourhood. This is obviously due to the deeper layers of water being forced to the surface by the tidal current running up the face of the incline. Similar cooling is noticed in all narrow channels, such as that at Row Point, in the Kyles of Bute, &c. In winter, also, the warmer water of the Minard Basin appears to overflow at Otter, and pour down the slope outwards. The same thing was observed at the mouth of Loch Goil.

No notice has been taken in the foregoing remarks of the estuary of the Clyde between Bowling and Greenock, or of the shallow lochs. The estuary is extremely shallow, and appears in all cases to follow the air temperature, and to be most influenced by it the further up observations are taken. Thus, in summer, temperature falls, and in winter it rises in proceeding from the river towards the sea. The shallow lochs similarly present many complicated features due to the temporary predominance of local variations over the regular seasonal changes.

Shallow water forms a comparatively small part of the Clyde Sea-Area, and on the whole the two sections to which reference has been made may be considered as including all the varieties of physical conditions nearly in the true proportion. Hence, if the mean temperature of these sections could be ascertained, it might be assumed with considerable confidence to be the mean temperature of all the water in the system.

To ascertain the mean temperature, the area of each colour on the section was measured by counting the squares it occupied on curve paper. This gave a statement of the relative prevalence of each temperature, and by multiplying each of these numbers by the mean temperature, adding together all the quantities so *obtained,* and dividing by the number of squares in the whole

area the average temperature of the section was ascertained, that is to say, the temperature it would assume if the whole mass of water could be thoroughly stirred up and mixed without loss or gain of heat.

The following tables give the figures arrived at in this way for each trip, first for the two main sections separately, and then for the two combined. It will be noted that there is always one temperature in far greater proportion than any other at the same date, and that this is most noticeable in winter and least in summer.

AREA AT VARIOUS TEMPERATURES.

Unit 1 Square Mile by 2 Fathoms.

I.—Section from Channel through Kilbrannan Sound and Loch Fyne.

Temp.	1886. April.	June.	August.	September.	November.	December.	1887. February.
40-42	1455	—	—	—	—	—	3
42-44	445	280	—	—	—	5	1050
44-46	—	1452	430	126	50	70	772
46-48	—	133	608	107	40	1825	75
48-50	—	30	393	666	413	—	—
50-52	—	5	229	433	1397	—	—
52-54·5	—	—	240	568	—	—	—
40-54·5	1900	1900	1900	1900	1900	1900	1900

II.—Section from Channel through Dunoon Basin and Loch Goil.

Temp.	1886. April.	June.	August.	September.	November.	December.	1887. February.
40-42	1109	—	—	—	—	—	33
42-44	145	333	14	—	—	4	1135
44-46	46	629	14	29	—	90	106
46-48	—	150	408	6	26	1206	26
48-50	—	120	500	10	47	—	—
50-52	—	58	204	152	1227	—	—
52-54·5	—	10	160	1103	—	—	—
40-54·5	1300	1300	1300	1300	1300	1300	1300

III.—Sum of both Sections.

Temp.	1886. April.	June.	August.	September.	November.	December.	1887. February.
40-42	2564	—	—	—	—	—	36
42-44	590	613	14	—	—	9	2185
44-46	46	2081	444	155	50	160	878
46-48	—	283	1016	113	66	3031	101
48-50	—	150	893	676	460	—	—
50-52	—	63	433	585	2624	—	—
52-54·5	—	10	400	1671	—	—	—
40-54·5	3200	3200	3200	3200	3200	3200	3200

Average Temperature of Combined Sections and Changes.

Section.	1886. April.	June.	August.	September.	November.	December.	1887. February.
Channel to Loch Fyne.	41·7	44·6	48·3	50·3	50·6	46·8	44·3
Channel to Loch Goil.	41·7	45·4	49·2	52·7	50·6	46·6	43·7
Combined Sections.	41·7	44·8	48·7	51·6	50·6	46·7	44·0
		3·1	3·9	2·9	—1·0	—3·9	—2·7

The average temperature of the whole mass of water must be

taken in connection with the temperature of surface water and of the air. The following tables and the curves in Figure 5 give these

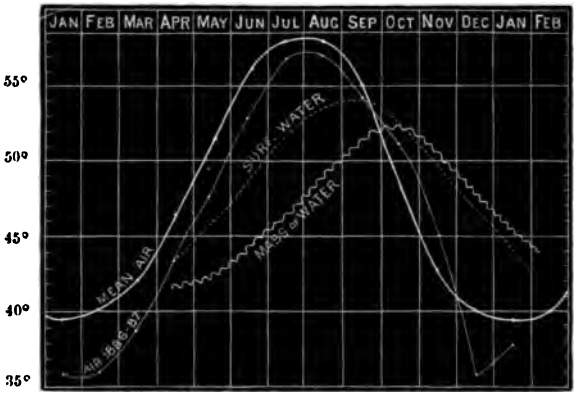


Fig. 5. Seasonal Variation of Air and Water Temperature.

MEAN TEMPERATURE OF SUPERFICIAL 2 FATHOMS OF WATER.

Section.	1886. April.	June.	Aug.	Sept.	Nov.	Dec.	1887. Feb.
Channel—Loch Fyne	43·1	48·5	53·8	53·0	49·2	45·7	43·3
Channel—Loch Goil.....	44·5	50·6	52·9	53·0	49.8	45·5	41·3
Combined	43·8	49·6	53·4	53·0	49·5	45·6	42·4

MEAN TEMPERATURE OF AIR OVER CLYDE SEA-AREA; AND DEVIATION FOR 1886-87.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Average, 1886-87...	39·5	40·0	41·5	46·0	50·5	56·0	58·0	58·0	54·5	48·5	42·5	40·0	39·5	40·0
Deviation, 1886-87...	— 3·5	— 4·0	— 2·5	— 1·5	— 2·5	— 2·5	— 1·0	— 1·0	— 0·5	+ 2·5	+ 2·5	— 4·0	— 2·5	— —

data. For the mean monthly air temperature over the Clyde Sea-Area, and deviations from the mean during the period of observation, I am indebted to Mr. Buchan, of the Scottish Meteorological Society. The average surface temperature is calculated for the

superficial two fathoms, in order to avoid the error of local and extremely superficial heating and cooling. The curves show that the winter, spring, and summer of 1886 were much below the average in air temperature, that the autumn was somewhat above the average, and the winter, 1886-87, again considerably below. Thus, the heating and cooling of the water would both be retarded, and the curves for water temperature be flatter than the normal.

When the autumnal equinox is past the air temperature, previously higher than that of the water, falls below the latter, and at the same time the curve of mean water temperature rises above that of surface temperature. During the period of heating these two curves are very considerably separated on account of the tendency of heated water to remain on the surface and get still hotter; but during cooling they keep much closer together, since the surface water no sooner cools than it sinks, and so chills the mass uniformly. The apparent exception to this general principle presented by the case of the deep enclosed mountain-girdled lochs, may be due to the fact that the surface water is always very fresh, and no amount of cooling will render it denser than the sea water beneath.

The following table gives the dates of each cruise, the number

Trip.	Begun.	Ended.	Lasted. (Days.)	Central Day.	Interval from last. (Days.)	Change of Mean Temperature.		Days per Deg.	Total Change of Heat.	Average Change of Heat per Day.
						Total.	per Day.			
April,	13th	21st	9	17th	—	—	—	—	—	—
June,	16th	22nd	7	19th	63	+3°·1	+0°·05	20	+465,000 × 10^6	+7,000 × 10^6
Aug.,	4th	12th	9	8th	50	+3°·9	+0°·08	13	+585,000 ,,	+11,600 ,,
Sept.,	22nd	29th	8	26th	49	+2°·9	+0°·06	17	+438,000 ,,	+ 9,000 ,,
Nov.,	11th	19th	9	15th	50	-1°·0	-0°·02	50	-146,000 ,,	- 3,000 ,,
Dec.,	23rd	31st	9	27th	42	-3°·9	-0°·09	11	-585,000 ,,	-14,000 ,,
Feb.,	3rd	12th	10	8th	42	-2°·7	-0°·07	15½	-405,000 ,,	- 9,600 ,,

of days between the central days of successive trips, the average daily change of mean temperature in the mass of the water, and the calculated change in the amount of heat present, using as a unit of heat the amount required to raise the temperature of one ton of sea water, 1° F. The average daily change of mean

temperature from April to February was $\frac{1}{17}$th of a degree Fahrenheit, corresponding for the whole mass of water to a change in total heat sufficient to alter the temperature of 9000 million tons of sea water one degree.

The total heat gained from April to September, 1886, by the water of the Clyde Sea-Area was 1,545,000 million ton degrees, shown by a rise in mean temperature of 10°·3; the total loss of heat from September, 1886, to February, 1887, was 1,200,000 million ton degrees, corresponding to a fall in mean temperature of 8°·0; thus leaving in the water 345,000 million ton degrees, or sufficient to raise the mean temperature 2°·3.

The yearly variations of temperature are unknown, and only the slenderest data are present to guess from. In the deep water off Skate Island observations were taken by Mr. Buchanan in August, 1878, and June, 1879, and by the Scottish Marine Station staff in August, 1885, and June and August, 1886. The results are:—

	28.8.78.	28.8.85.	10.8.86.	25.6.79.	21.6.86.
Surf., ...	58·4	54·8	53·6	51·6	48·3
Bot., ...	48·2	47·6	45·6	42·6	44·0

What is aimed at in the present investigation is to have a record of the temperature changes taking place during an entire cycle of heating, cooling, and heating again throughout the whole of the complicated water system of the Firth of Clyde and its lochs, and to do this with a degree of precision and completeness never before attempted in similar work. When the observations have all been collected, the most laborious part of the research will be still to commence in the arrangement and discussion of results.

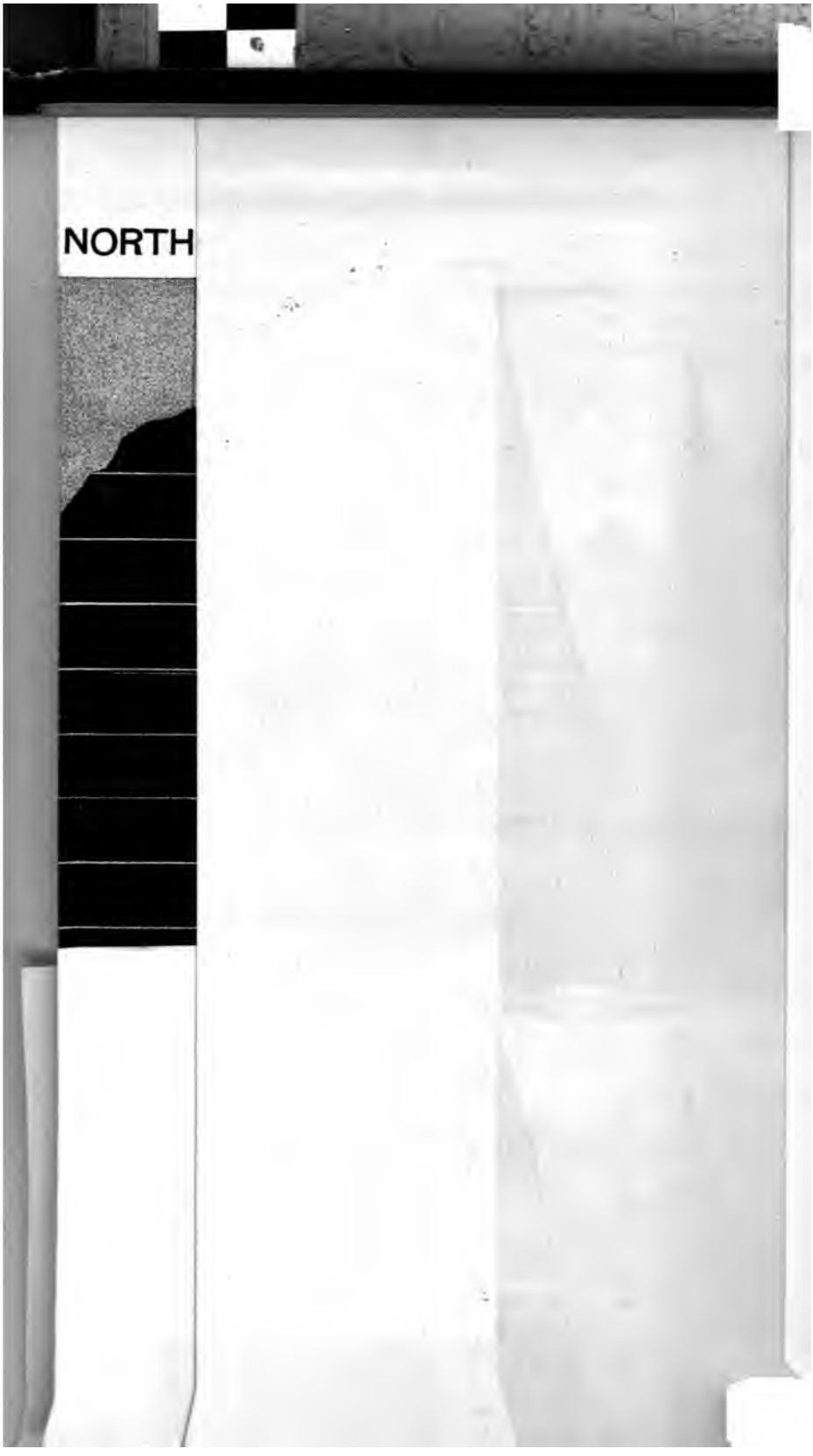
At present the work is not in a sufficiently advanced state to justify any applications of the facts ascertained to other sciences, but two indications of possible conclusions may be stated. It has been observed that throughout almost the entire year, alike when the sea-area is cooling and warming, the Channel is warmer than any other part of the system. Hence, while much of the heat that raises the temperature of the mass of water in summer comes in from the Atlantic, none of it appears to go out again in that way. The whole heat, alike that radiated directly by the sun, communicated by heated air and driven in by tides, leaves the water either latent, in the form of evaporated water, or as radiation into space through the air, and hence the air must be warmed to a greater degree by the water of the Clyde sea-area than it would be, for instance, by the water of an equal area of the Firth of Forth.

The other point is the influence on life; and with regard to this it will be sufficient to copy the following notes from a letter from Mr. David Robertson of Millport, the eminent naturalist:—

"On February 4th, in Upper Loch Fyne, Mr. J. Murray, of the *Challenger* Expedition, attached three tow-nets to the trawl line, one net to the beam of the trawl at a depth of 70 fathoms, another to the trawl line at 20 fathoms from the bottom, and the third at 40 fathoms from the bottom. The temperature of the water at the bottom net was 45°·9, at the middle net 46°·3, and at the upper one 45°·6. In all three nets copepoda were moderately abundant. The bottom net and the one nearest the surface contained one and the same species, but the contents of the net at the middle depth were different, confined to an abundant species of a copepod loaded with ova. With them there were two or three adult schizopods *(Nyctiphanes Norvegica)*. As the middle water of the loch at this time is shown to be warmer than either the layer above or below, we may reasonably assume that the species in ova sought the warmer layer. I have often noticed that the gatherings taken during summer from the surface (not deeper than four or five inches) contained more larval forms than those taken two or three feet deeper.

"On 10th February, 3½ miles off Davaar Island (Campbeltown), three nets were attached to the sounding line, one at the bottom in 26 fathoms, another at 13 fathoms from the bottom, and one at the surface. The temperature from bottom to top was the same, 43°·8. All three nets contained copepods exclusively of one and the same species, with the exception of a few of the infusorian *Sagitta bipunctata* shared only by the two lower nets. There was very little of any kind in the surface net.

"The vast multitudes of these minute forms that swarm in our seas both summer and winter must yield a rich harvest to those that feed and fatten on them, and which in their turn yield supplies to higher orders. . . . If we had a better knowledge of the haunts and habits of these small animals, the food of fishes, we would most likely have a better knowledge of the fishes themselves. For instance, as it is, if we were to find in the Firth of Clyde a herring with its stomach filled with adult *Nyctiphanes Norvegica*, we could with tolerable certainty say that it had been feeding on or near the bottom, at a depth between 40 and 100 fathoms."


NORTH

XXXI.—*Introduction of Sea Water into Glasgow.* By JOHN ANDERSON.

[Read before the Society, 2nd March, 1887.]

THE idea of introducing salt water into Glasgow is not original. About twenty years ago the late Mr. Morris Pollok, of Govan, advocated the utilizing of the Corporation engines, "Samson" and "Goliath," for pumping salt water up from Gourock.

The fact that a gentleman of matured experience should have recognised the advantages of bringing salt water into the city gives me the hope that you will look upon the following scheme as worthy of consideration.

In advocating the introduction of sea water into Glasgow I will keep clear of unnecessary detail, and will merely look at the scheme from the three broad standpoints of—

I. Can it be done?
II. What would it cost? and
III. Should it be done?

On looking over the Ordnance Survey Map, a number of positions on the Clyde present themselves as apparently suitable for the purposes of such a scheme, but a careful examination will show that there is no position so suitable as Saltcoats. Some places from which salt water could be taken are nearer to Glasgow, but they present some greater obstacle or objection. For example, the distance from the West Bay or from Kempock Point at Gourock is 25 miles, or 4 miles nearer to Glasgow than Saltcoats, but the cost of works, owing to the position of the reservoirs, would probably be as great; and a more serious objection is the character of the water itself, which is too much of the "half-and-half" element to be of much benefit. The Irvine route is also 2 miles nearer to Glasgow than the Saltcoats route, but the ground gradually rises until, at a distance of 15 miles from the coast, it reaches a height of 749 feet. This would, of course, cause the cost of pumping to be much too expensive.

I have therefore come to the conclusion that there is no better position on the Clyde than Saltcoats, because there, within a reasonable distance from the coast, will be found sufficient elevation for the reservoir, while the rocky shore and the fine strong sea water cause this position to be most favourable for the purposes of such a scheme.

A glance at the accompanying plan (Plate XII.) will show the suggested route. The water is taken from the sea at Saltcoats. The pipe is laid along the public road, passing through Dalry, Beith, Elderslie, Paisley, Ibrox, and into Glasgow—a total distance of 29 miles. At one point the pipe leaves the road in order to avoid high ground. The reason for using the public road is because it is cheaper to lay a pipe there than through private ground. There is a prevalent idea that to lay a pipe along the railway would be a cheaper method; this is a mistake—the railway being at a lower level would necessitate a thicker pipe to resist the extra pressure, the cost of the pipes would therefore be greater; there would also be a heavy annual rental for "way-leave," and the risk of damages caused by pipes bursting would be very great.

The sketch of the elevation shows the position of the reservoir and the different heights between it and Glasgow. The pumping engines are placed at Saltcoats, the water is pumped up to the reservoir which is situated about half-way between Saltcoats and Dalry, at an elevation of 360 feet above datum line. The highest intervening point between this and Glasgow is 300 feet; the highest point of Glasgow is 180 feet. The water would therefore flow from the reservoir into Glasgow without interruption, and would rise considerably above its highest level. At Kelvinside it would rise to a height of 200 feet by day and 250 feet by night.

As to the engineering difficulties—no doubt they are considerable, especially between the sea and the reservoir, but these difficulties to men like our city engineers, who carried out, and who are at present extending, our magnificent fresh-water supply, would hardly be considered difficulties at all; in fact, the professional gentleman to whom I am indebted for the calculations for this scheme is of the opinion that most undoubtedly it can be done.

As the cost of carrying out a scheme such as this in its entirety would be very great, it might be advisable to try it on *a modified* scale, and then, when the citizens realized its benefits,

and if it was found that the scheme would pay, the pipes and engines could be duplicated and the scheme gradually extended.

I think a reasonable and a useful quantity of sea water to take as a basis would be 10 million gallons per week, or 520 million gallons per annum. The works to supply this quantity of water would cost about £210,000. This sum includes pumping engines of 250 horse-power nominal, 24-inch main pipe, cost of reservoir, piping to each of the public and private baths, Act of Parliament, 10 per cent. for contingencies, and all necessary works. Of course, the calculations are approximate; it would be impossible to get at the exact cost without issuing schedules to contractors. The sum allowed for Parliamentary expenses would be exceeded in the event of the Bill being seriously opposed.

The 10 million gallons per week has been taken as a basis, because there can be little doubt that this quantity could easily be disposed off at a payable rate, and also, because in the event of a larger quantity of water being required, it would be more advisable to have duplicate pipes and duplicate engines than to have a larger single pipe. A duplicate reservoir would not be necessary.

A total cost of £210,000 represents an annual outlay of £18,000 per annum, being £10,500 for interest on money and sinking fund, and £7,500 for working expenses.

The water might be disposed off according to a sliding scale something like the following:—

For any quantity from 80,000 to 100,000 gallons per annum,	1s. per 1,000 gallons.	
For any quantity from 100,000 to 500,000 gallons per annum,	10d. ,, ,,	
For any quantity from 500,000 to 2,000,000 gallons per annum,	8d. ,, ,,	
For any quantity from 2,000,000 gallons and upwards,	6d. ,, ,,	
A minimum charge being £4.		
Of this quantity of water the public and private bath companies would require, say, 80 million gallons, at 6d. per 1,000,		£2,000
And, say, 4,000 families at £4 each,		16,000
		£18,000

Last year the swimming baths used 117 million gallons of water, but as sea water would be used principally for the swimming ponds, 80 million gallons should be ample. At present the public baths are supplied with Loch Katrine water gratis, but the additional revenue from the baths if they were supplied with sea water would, I consider, more than compensate for the cost of the water. In support of this statement, the Cornwallis Street Baths, Liverpool, may be mentioned. In 1880, with fresh water, the number of bathers was 96,685, and the income was £1,638 2s. 5d. In 1884, after salt water was introduced, the number of bathers rose to 114,896, and the income to £1,968 7s. 9d. The only other analogous case I can find is that of the Greenock Bath Company. The secretary states that the average daily number of male bathers in summer when the pond was supplied with fresh water was 30, after salt water was introduced the number increased to 80, and among the lady members the contrast was still greater.

If the Glasgow baths were supplied with sea water the increase of bathers would probably be much greater, because our water would be far superior to either that of Liverpool or Greenock. The water for both of these places requires to be filtered.

As to 4,000 families at £4. There might be some question as to this number being likely to use the water, but when the route of the pipe is taken into consideration, the number of villas along or near the route, and the very large number of families in the suburbs who would be certain to have it, I think that there is very little doubt that the full quantity of water for disposal would be at once taken up.

The objection presents itself that in a scheme such as this Glasgow would benefit the suburbs quite as much as the city. The number of dwelling-houses in Glasgow above £20 rental is gradually decreasing, simply because people who can pay more than £20 prefer living in the suburbs; it would therefore be impossible to introduce sea water into the city at a cheap rate without supplying a large proportion to the suburbs, in fact, it would be to the advantage of the city to supply as much water as possible beyond the boundaries. The more water disposed of beyond the boundaries the cheaper the water would be for the city itself. The quantity of water to which a small consumer would be entitled for his £4 would be 80,000 gallons, which is equal *to 670 fills* of an ordinary plunge bath, or two baths per day.

It might be considered advisable to supply a smaller quantity at an increased rate, but this is a matter of detail which could only be found out by experience.

If, in addition to the 80 million gallons required by the swimming ponds, the whole of the 4,000 families used the full supply to which they were entitled, there would still be left a surplus of 120 million gallons, which could be distributed gratis by standpipes in different quarters of the town for those who chose to use it. It is highly probable, therefore, that the scheme would not only pay itself, but would leave a very large proportion of sea water for free distribution.

It has been suggested that a public company should be formed to introduce sea water into the city, but this I think would defeat the grand aim of the scheme, which is to supply as much water as possible at the lowest possible rate, with the view of improving the health of the community. A public company could not carry out or manage a scheme like this so efficiently or so economically as the Corporation; nor is it at all likely that the Corporation would allow a public company to carry out a scheme which might in some instances clash with the interests of the Water Commissioners.

The introduction of sea water into Glasgow would undoubtedly prove beneficial to the inhabitants, but more particularly would it be of benefit to the rising generation. To the poor and to the better classes alike it would be not only a benefit but a luxury. The poorer classes would have sea water at their very doors, the better classes could have it into their houses. Those popular institutions—our public baths—which must be doing a great amount of good, both physically and morally, to the young men of Glasgow, would become still more popular and would consequently do still more good.

Dr. Sydney Ringer, in his work on Therapeutics, says—"It is scarcely necessary to occupy much space in a description of cases in which sea bathing may be usefully employed. In chronic illnesses with debility sea baths yield the best results; but it is useful specially to convalescents from acute disease, to those whose health has been broken by overwork, by residence in towns with a too sedentary employment, or injured by excesses of various kinds."

I have called on several of our leading medical men and have asked their opinion as to whether they considered that the

introduction of sea water into Glasgow would be of benefit to the inhabitants.

One gentleman said "it was difficult to realize the benefits, they would be so great;" another says—"Sea water baths, cold or warm, when judiciously employed, whether for personal gratification, or for prevention, alleviation, and cure of disease, or the restoration of renewed vigour to the worn-out and exhausted, are agreeable, refreshing, and remedial agents of a very high order; where common water baths would relax—fatigue and relax—sea water baths give comfort, stimulate, and refresh. In many diseases characterised by debility and diminished vital powers, which manifest themselves particularly in childhood and youth, sea water baths exert a bracing and tonic influence upon the system and prove highly restorative and beneficial;" and another of our leading medical gentlemen says — "While offering no opinion as to the financial or engineering aspects of the question of the introduction of sea water to Glasgow, I have yet no hesitation in saying that, on hygienic grounds, great benefit would accrue to the citizens from the habitual use of sea water bathing. Sea water is more tonic in its action on the system and more stimulating to the skin than fresh water, and the advantage of having it in public baths and in one's own house would be very great, especially to the young. In scrofulous and chloratic conditions of the system sea bathing is recognized as a valuable remedy; and during the period of growth, especially if there be some debility, the use of sea baths at suitable temperatures is doubtless of great value. If bathing in sea water could be largely practised in Glasgow by the young, it would greatly contribute (along with improved dietary) to lessen the amount of rickets and other diseases of development which prevail."

In short, there seem not to be two opinions as to sea water proving beneficial to the inhabitants; the whole matter seems to reduce itself to the point—"Is it worth the money?"

Our Councillors have already undertaken many great works with the view of improving the health of the community, such as the City Improvement Scheme, which has cost an average of 2½d. per pound since its commencement in 1866. Our Public Baths cost the ratepayers one-third of a penny per pound, exclusive of water, sinking fund, and depreciation. The introduction of sea water forms a sort of natural appendix to *these great* schemes, and although it is a very small affair

compared with them, it would, even in the modified scale indicated, undoubtedly prove beneficial to the inhabitants, and when in working order would, I believe, cost the ratepayers nothing.

The quantity of water mentioned—520 million gallons per annum—may seem a very small matter, and not worth the labour it would involve; but it should be remembered that the quantity is quite sufficient to test the scheme, and to attempt more would hardly be judicious, while the experience gained would act as an index for future guidance.

If it is the case that sea water can be introduced into the city, that it would be beneficial to the inhabitants, and that there is very little likelihood of any tax being required, then surely the scheme is worthy of a trial; and I venture to think that if our Town Council could see their way to enter into a scheme such as this, they would meet with the hearty support of the citizens of Glasgow.

APPENDIX.

The following are the quantities of water required to fill the various Swimming Ponds:—

	Gallons.		Gallons.
Greenhead, -	93,750	Victoria, -	90,000
N. Woodside,	93,750	Arlington, -	84,000
Townhead, -	96,875	Western, -	83,000
Gorbals, -	100,544	Dennistoun,	69,300
Cranstonhill,	104,256	Bellahouston,	60,000
	489,175		386,300

Total, - - - 875,475 gallons—

being about 44 million gallons per annum, allowing for the ponds being filled once every week. The balance of 36 millions should be quite sufficient for showers, hot baths, and keeping the water in pond up to its proper level.

The rental of dwelling-houses above £20 in Glasgow is about £300,000, which is gradually diminishing, the adjoining burghs being principally formed from this class of tenants.

The rental of dwelling-houses above £20 in the suburbs is as the following:—

Hillhead, - - - -	£83,000
Kelvinside, - - - -	£83,000
Pollokshields E., - - -	£44,000
Pollokshields W., - - -	£32,000
Crosshill, - - - -	£24,000

e XII, Vol. XVIII.

XXXII. — *On Foulis' Gas-Fire: A New Departure in using Gaseous Fuel for Domestic Purposes.* By the SECRETARY.

[Abstract of Paper read before the Society, 5th January, 1887.]

WHEN a hitch occurs in providing a supply of papers for any particular meeting of a society such as our own, it is generally understood, I believe, that the Secretary should always be ready to step into the breach. Acting on that understanding, I appear before you this evening to occupy a portion of the time, as, owing to a misunderstanding, an important paper that has been promised to the Society, through your President, is scarcely yet available. I had no desire to thrust myself before the Society to submit any formal paper, but as the holidays were at hand I found that it was practically impossible to secure any other person ready and willing to fill up the gap. That is my only excuse for offering, at this time, some remarks on the subject mentioned in the billet convening the meeting. I should, perhaps, also explain that in bringing forward this subject, I alone am responsible, as the inventor of the gas-fire which I am about to describe was very unwilling that it should be brought forward here lest the act of doing so might be regarded as one having an advertising tendency.

Having for several months watched the progress of the invention until it has reached its present comparatively perfect stage, and knowing that in working it out our fellow-member, Mr. Foulis, has successfully applied a most important principle of physical science which has hitherto been but little known amongst persons who have to work processes involving the use of very high temperatures, I felt quite assured that the gas-fire to be described was worthy of our consideration on scientific grounds alone; and it is on those grounds that I present it to your notice.

Some of you may be aware that Mr. Frederick Siemens, brother of the late Sir William Siemens, has, during the last two years or so, brought under the notice of scientific men generally, and of metallurgists in particular, the important fact that the full value

of flame-heat in furnaces is only obtainable when the flame is allowed to spend itself without coming into direct contact with red-hot surfaces, whether they be of metals in the molten state or of solid brickwork, &c. Mr. Siemens has on several occasions, and more especially before the members of the Iron and Steel Institute, dwelt very forcibly upon this principle, and he has given various excellent illustrations of its truth, all drawn from practical experience in working steel-melting, glass-melting, and other furnaces where intense heats are generated. It is this same principle that Mr. Foulis has turned to practical account in devising his gas-fire. The gaseous fuel, in admixture with the necessary quantity of air, is inflamed at the mouths of a series of Bunsen burner tubes, and the resulting flames burn in a separate combustion chamber before the current of hot gases is allowed to impinge upon the surface of the material which it is desired to render incandescent. It will thus be seen that the aim of the inventor has been to get as perfect combustion as possible without any direct contact of the flame with solid matter. In carrying out his endeavours he has been highly successful—so successful, indeed, that for heating effect this gas-fire has no equal, if we take equal gas consumption and equal heating surface into consideration. The "Foulis" gas-fire also takes advantage of another important principle, that of heat-regeneration, which was so extensively applied in various kinds of furnaces by Sir William Siemens, and which Mr. Foulis, in conjunction with that gentleman, has extensively adopted in the retort furnaces at Dawsholm and Dalmarnock Gas-works.

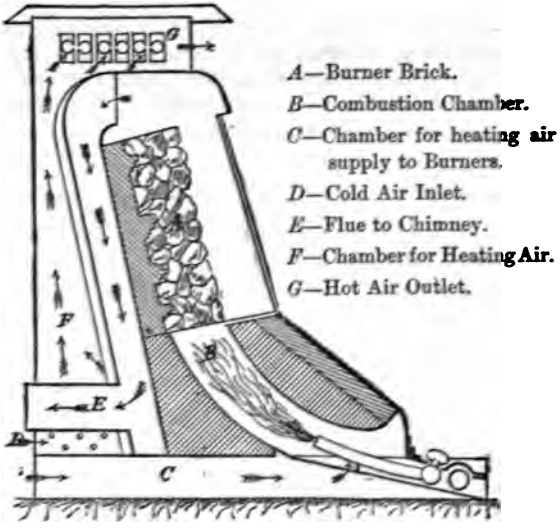
In the "Foulis" fire the air required for the combustion of the gaseous fuel is raised to a high temperature before it is allowed to mix with it; and in this way the calorific power of the gas is very greatly increased. In its most perfect form this gas-fire provides a current of warm, fresh air, which is distributed through the apartment in which the fire is placed, and the heat which is imparted to this current of air is abstracted from the effluent waste gases on their way to the chimney. The fire is thus seen to be a practical embodiment of three important scientific principles.

By reference to a large diagram on the wall, the author showed that, as an essential feature of the invention, there was a hollow fire-brick the hollow space in which is the combustion chamber (B in the accompanying figure). In this chamber the gas is burned, *and without*, if possible, the flame coming into contact with the

walls, which are themselves formed of four special fire-bricks. It was worthy of remark, he said, that the flame never came into contact with the cast-iron plates forming the outer shell of the gas-fire. In another chamber, or passage, the principal air supply to the burners was admitted; and, in this chamber also, the principle of heat-regeneration was taken advantage of. Extending all over the back and both sides of the fire there was a third chamber, or space, through which the cold, fresh air was admitted, which was eventually delivered into the atmosphere of the room in the heated condition, the said air being exposed in that space to a large extent of heating surface. The hot gaseous products of combustion, after passing through what was known as the "burner brick," ultimately found their way to the chimney, in their course giving up a large quantity of their heat to the fresh air formerly spoken of, and which was at length discharged into the room through a series of apertures immediately underneath the top of the fire.

FOULIS' REGENERATOR GAS-FIRE.

SECTIONAL VIEW.



Proceeding to describe the "burner brick" with some detail, the author stated that it was formed of fire-clay of special quality, and that it was of peculiar construction. Its front portion was formed of an irregular fretwork, the aim of which was to resemble,

as closely as possible, a mass of brightly-glowing coal or coke. This brick reached all the way across the gas-fire, and it was generally seven or eight inches high, and about three-and-a-half inches in thickness. It consisted essentially of two portions. The posterior half had a plain, solid surface, where it was set against the anterior portion of the air-heating space, and the front portion of the brick was formed of the irregular fretwork previously referred to, its individual parts being separately moulded by hand out of soft, plastic clay. Along the bottom edge of the "burner brick" there was a series of openings, each of which was opposite to one of the Bunsen burner tubes. These openings were shown to communicate with numerous irregular passages, so that the upward progress of the current of hot gases might be as much baffled or interrupted as possible. When the "burner brick" was properly fashioned, and the gas-fire was going well, the lower portion of the brick should become incandescent, even to whiteness, while the upper portion was of a more or less bright red; and such a fire was one of the very best "make-believes" that had yet been brought under public notice.

NOTE.—The gas-fire described was designed for consuming about 36 cubic feet of gas per hour. Through the kindness of Messrs. R. & A. Main, a typical example of this invention was fitted up on the lecture table and shown in practical operation during the evening. Much interest in it was displayed by the members present.—J. M.

XXXIII.—*An Experimental Research on the Artificial Cultivation of Vaccine Lymph, with observations on the nature of Vaccine and the Immunity produced by Vaccinia.* By NEIL CARMICHAEL, M.D.

[Read before the Society, 19th January, 1887.]

NORMAL vaccine lymph is a colourless transparent liquid, in chemical composition resembling the plasma of blood, and containing solid particles of various kinds. It is rich in albuminous substances, and contains salts, mainly phosphates of alkalies and alkaline earths, which give to it a slightly alkaline reaction. Under the microscope the particles held in suspension are found to be leucocytes (white blood corpuscles, or pus cells), epithelial cells from the skin, large multinuclear cells, numerous irregular particles, probably the debris of cells, and micrococci. These micrococci* may be found free or variously grouped, not infrequently forming chains, but as a rule massed, without any evident system of grouping. They are minute colourless motionless transparent spherules, in diameter about the twenty-thousandth of an inch, and are probably vegetable and parasitic† in their nature. They multiply by fission, and when planted in a suitable soil, as in the skin of a child or a calf, they multiply with great rapidity. These micrococci are invariably present in vaccine lymph, humanized or calf, and no other organisms are found. It is now pretty generally conceded that these micrococci are the specific agents in vaccine lymph which produce vaccinia. Experiments by Chauveau,‡ Burdon Sanderson,§ and others, have demonstrated that the liquid portion of the vaccine lymph, that is to say, the vaccine lymph freed by filtration or deposit from its contained particles, does not produce vaccinia, and that the particles, on the other hand, are capable of producing the disease. But which amongst the particles produces the disease? We

* "Micro-organisms and Disease," Klein, p. 47. "Le Bactéries," Cornil and Babes, p. 535.

† Braidwood and Vacher.

‡ Comp. Rend. Acad. d. Sc., Paris, t. lxvi. 1868.

§ Report on "Intimate Pathology of Contagion."

cannot attribute the active agency to the leucocytes, because these are inflammatory products, and are fewest in the most active lymph; nor to the epithelial cells or the granular debris, because these are really necrosed particles, the products of the inflammatory and specific action within the vesicles, and, like the leucocytes, are least to be found in the purest and most active lymph. Nor can we attribute it to the large multinuclear cells which are few in number, which are evidently tissue cells proliferating, and which are few in active lymph; nor to blood cells or other adventitious particles. There remain, then, only the micrococci to which we can ascribe the active agency in the production of vaccinia. That this is so is supported by the following considerations:—*First*—They are invariably present in vaccine lymph; they are uniform in size and other characters; they are abundant in the purest and most active lymph. *Second*—They are the only living organisms found in vaccine lymph. *Third*—They multiply enormously when the lymph is planted on the calf or human subject, in the vaccinated tissues, and subsequently in the vesicles; and this active proliferation is coincident with the active development of vaccinia.* *Fourth*—They resemble organisms which are found in some other infectious diseases, such as erysipelas and pneumonia, which have been proved to be the specific factor in the production of these disorders. And so we are, I believe, justified in assuming that these micrococci are the active agents in the vaccine lymph which produce vaccinia. It is interesting to note that smallpox virus contains microbes almost, if not indeed absolutely identical, in appearance with those of vaccine lymph.†

When vaccine lymph is inserted into the skin of an infant, besides reproducing itself in increased quantity, it produces the specific disease vaccinia. This specific disease in some way modifies the condition of the subject for years, so that lymph subsequently planted in the skin will not develop and vaccinia cannot be produced. Besides this it is found that the vaccinated subject is much less susceptible to, or is entirely protected against, smallpox, so that the micrococci of vaccine lymph and smallpox are now incapable of developing on this soil. In what manner the development of vaccinia and the multiplication of the

* Braidwood and Vacher.

† Cornil and Babes. Warlomont's "Manual of Animal Vaccination," *page 3.* Klein, "Micro-organisms and Disease," p. 47.

microbes produce the protection or insusceptibility just considered is still unsettled. Various hypotheses* have been suggested. The first theory is that of exhaustion. It is assumed that the microbes entirely use up or destroy some material in the system which is necessary, that is to say, which constitutes the food or a necessary portion of the food of these organisms. Against this it may be stated:—*First*—That we do not know any such material; *Second*—That any normal constituent of the body, if removed, would in all probability be speedily renewed; and *Third*—That such microbes of disease as are familiarly known to cause insusceptibility to their own further growth in the protected subject, can be grown in infusions of the tissues of the protected subject, and in comparatively simple infusions. The second hypothesis is the so-called vital theory. This supposes that, on the microbes beginning to multiply in the system, a struggle for supremacy takes place between the tissue cells and the microbes, which, when the tissue cells are victorious, results in the cessation of the disease and an increase of vital energy, such as renders the tissues insusceptible to the further action of those microbes. This is poetical, but it has not much beyond that quality to recommend it. It is curious, besides, that the increased vital energy should not also enable the system to resist the attack of other infectious microbes. The third hypothesis is the accidental theory. It is assumed that in the process of growth the microbes give to the system chemical products which are [illegible] inhibitive to the organisms producing them. Thus, yeast is planted in grape juice containing tartaric acid and [illegible] acid, until the production of alcohol [illegible] per cent. After this point is reached growth of yeast ceases because [illegible] yeast. It is [illegible] organisms. [illegible] again sustain the [illegible] of growth [illegible] been removed [illegible] been added [illegible] prevents the [illegible] very similar [illegible] the yeast [illegible]

* Hannal [illegible]

of *mycoderma aceti* acts towards this organism as does the alcohol toward yeast, arresting further growth, and, if in large proportion, destroying the organism which produced it. The same holds good with the lactic ferment, the butyric ferment, and others. The same also holds true of the cells of the higher organisms, including man. The secretion of the gastric cells, when in contact with these cells, restrains their further secretion.* It may indeed be looked upon as a general law of biology, that the chemical products of living organisms, when retained in contact with these organisms, check or arrest their functions or perhaps even destroy the organisms.† If then the chemical products of the growth of the vaccine micrococci pass into the circulation of the body and into the tissues, it is not hard to suppose that when a certain degree of saturation is produced the tissues will no longer support the life of the microbes, and so long as these products remain in the tissues the subject will be proof against the further development of vaccinia.

In vaccinating we have the choice of two kinds of lymph, calf and humanized.‡ It is objected to the use of humanized lymph, *First*—That it is inferior in potency and in protective power to calf lymph, and to the humanized lymph as first used by Jenner. It is supposed by cultivation in the human subject to have become so modified that it is less violent in action and produces a less degree of protection. *Second*—It is objected that there is great risk of transmission of disease from child to child with the lymph. This danger is, however, with care on the part of the operator, an exceedingly slight one, few instances being known in which the transmission of disease has been definitely proved. *Third*—It is objected that the supply of humanized lymph is unequal to the emergency of an epidemic of smallpox.

Against the use of calf lymph it is objected, *First*—That it is unnecessarily violent in its action, and it is not yet certain that it is of higher power in protecting against smallpox. The greater virulence of its action does not necessarily imply greater specific power, and it is well known that its infecting power to the human subject is less than that of humanized lymph, much greater care

* Klein, p. 171. "Micro-parasites in Disease." Preface, p. 12. Dr. Watson Cheyne.

† "Pathological Mycology." Woodhead and Hare, p. 17.

‡ "Vaccination" Article by Dr. Collie in Quain's "Dictionary of *Medicine*," p. 174. Warlomont. Seaton.

being necessary to secure successful vaccination with it. This lessened infective power may, however, be due simply to change of soil, and it does not necessarily imply lessened protective power. *Secondly*—It is objected that calf lymph may be the means of transmitting to the human subject the diseases of the calf, such as tubercle; and it is much more easy to select a healthy child than a healthy calf.

This being the present position of the question of vaccination, it suggests itself at once to us that if we can cultivate the microbes of vaccinia in some suitable soil which is harmless, and retain the infecting and protecting power, we meet all the objections raised to the use of calf or humanized lymph. We would have the certainty that no other disease was transmitted, and we would be able to produce lymph in unlimited quantity.

More than ten years ago I took up this line of inquiry, and have been since then more or less continuously engaged in the research, and, so far as I am aware, I was the first to make the attempt, and for many years was the only worker in this line. It was suggested to me *(a)* by the prediction of Sir Joseph Lister—whose class of Surgery I had the privilege of attending "That all infectious diseases would be found to be due to living organisms;" *(b)* by the fact that Pasteur and Koch had proved that certain diseases, which they had specially studied, were due to these organisms, had cultivated these organisms outside the body, and had by these cultivations been able to reproduce the disease; and *(c)* also by the fact that I had been specially engaged in the study of vaccination.

In 1883 the Worshipful Company of Grocers of London offered a prize of £1,000 for the discovery of a "Method by which the vaccine contagium may be cultivated apart from the animal body, in some medium or media not otherwise zymotic; the method to be such that the contagium may by means of it be multiplied to an indefinite extent in successive generations, and that the product of any number of such generations shall (so far as can within the time be tested) prove itself of identical potency with standard vaccine lymph."* My experiments on the subject, which were begun seven years before the offer of this prize, have all along aimed at similar results, under conditions similar to those named. I have, however, not claimed the prize, as I have not been able,

* Grocers' Company advertisement.

nor, as yet, has any other, to fulfil all these conditions. Such results as I have obtained I propose to lay before you.

I do not propose to lay before you my experiments in a chronological order, or to tabulate them all, as that would only weary you with a long account of failures. It will best serve our purpose to sketch shortly the various methods employed, and to consider carefully such positive results as have been obtained. In beginning this investigation a number of preliminary points presented themselves for consideration. It was necessary to obtain the lymph and to cultivate it under such conditions as would secure that no organisms other than those of the lymph should gain access. To secure this,* it was necessary that all apparatus should be sterilized by heating or by steeping in some antiseptic solution, such as solution of bi-chloride of mercury, that the soil should be aseptic or should be disinfected by heat, and that the lymph should be collected and transferred to the soil in such a manner as to obviate or reduce to a minimum the danger of contamination with extraneous organisms. Test tubes and flasks, into which cultivating soil was to be placed, were plugged with cotton-wool stoppers, and were then placed in an iron box and heated to 300° F. for an hour or so, thoroughly to sterilize them. The glass cups and shades and the plates used for making the cultivations on potatoes were sterilized by steeping in a watery solution of bi-chloride of mercury, of strength 1 to 100. Fresh tissues and blood were taken from newly-killed animals under a carbolic acid spray, by means of sterilized instruments, into sterilized vessels, and immediately closed by sterilized wool plugs enclosed in gauze, if a large surface required to be covered. Eggs were taken, as fresh as possible, washed in an antiseptic solution, and wrapped in cotton wool which had been sterilized by steeping in an ethereal solution of carbolic acid and dried. White of egg was taken into a beaker with glass cover and glass sole-plate, which had been steeped in a solution of carbolic acid and heated so as to drive off the acid and leave them in an aseptic condition. Milk, whey, soups, and animal infusions of various kinds were boiled and received into sterilized flasks and test tubes, with sterilized cotton-wool plugs, and heated in steam to about 212° F. for an hour on three successive days. Potatoes were sterilized by thoroughly washing and brushing the skin, then steeping them for

* The methods were the same in principle, and frequently also in detail, *as those* described by Klein, Woodhead, Hare, Koch, etc.

an hour in a solution of bi-chloride of mercury, and finally steaming them for half an hour at 212° F. These and many other precautions were adopted to render it certain that the apparatus and the soil used were themselves free from organisms. It may perhaps be doubted if such precautions were necessary. That they were, is, I think, evident from a few considerations. All successful cultivations, known technically as pure cultivations,* of other infecting organisms have been made with somewhat similar precautions, and all who have made these investigations insist on the necessity of such care. And while it is the case that the vaccine virus can grow and multiply in the human body along with other infective organisms,† and perhaps outside the body may be able to grow mixed with other organisms, what we wish to obtain is a cultivation of the organisms contained in vaccine lymph, in a pure condition, unmixed with any other organisms, so that we may be certain that the microbes cultivated are the actual development of those in the lymph, and are uninjured by admixture of any other form of life.‡

The next point which presents itself to us is whether the lymph should be planted on a free surface or immersed in a liquid. In the ordinary process of vaccination the lymph is planted locally on the arm of the child, or near the udder of the calf. In my earlier experiments I immersed the lymph in liquids. So treated, the micrococci rapidly multiplied, but I did not find that they retained their infecting power. In my later experiments, having seen an account of Koch's gelatine process of cultivating organisms, I adopted various modes of planting on a fixed surface, as on potatoes (Plate XIV., Fig. V.), turnips, and animal tissues, and on soups and other organic fluids thickened with gelatine or Japanese isinglass, known as agar-agar (Plate XIV., Figs. VI. and VII.), which does not liquefy at the highest temperature necessary for cultivation. It was found that on these the growths, though active at first, especially with the secondary cultivations, gradually became slower and finally stopped long before the surface of the soil was covered. I concluded that either the suitable nutriment in the neighbourhood was used

* Koch in "Micro-organisms and Disease," p. 32 *et seq.*

† Vaccinia may develop in presence of syphilis, measles, and other diseases. It may develop even along with smallpox, if inserted during the period of incubation of the latter.

‡ See Koch on pure cultivations in "The investigation of pathogenic organisms," as translated in "Micro-parasites in Disease," by Cheyne.

up, which, however, was unlikely, or that the neighbouring soil had become saturated with the chemical products of the organisms, and had so become in a measure protected or insusceptible as regards further growth of these organisms.* I adopted various plans of planting the lymph on a fixed surface to which nutrient fluid was freely supplied. I suspended into the liquid, in test tube and flasks (Plate XIV., Fig. III.), pieces of linen and flannel held in position by platinum wires which passed through the cotton-wool plug. The lymph was planted on the cloth above the liquid, the lower end of the cloth by capillary attraction drawing up the nutriment and carrying away the chemical products. I also adopted the method, which I found more satisfactory, of placing a piece of marble in the liquid in the flask (Plate XIV., Fig. IV.), the marble being large enough to reach above the surface of the liquid. The lymph was planted on the marble, and nutriment was supplied and the chemical products were removed by the capillary movements of the liquid on the marble. This plan had the additional advantage that it neutralized any acid which might be formed in the preparation of the nutrient fluid or in the growth of the organisms. As to the kind of soil to be employed, it seems desirable to approximate as closely as possible to the nature of the tissues of the calf on which we know that vaccine thrives. Portions of the heart, liver, brain, and other organs of the calf, were tried. Calf blood and serum also were employed. The eyes of calves were also used, the lymph being inserted into the aqueous and vitreous humors, the eye being maintained in an antiseptic condition. Also, the vitreous and aqueous humors were taken into sterilized watch glasses and lymph planted on them. Infusions of veal alone, or with peptone and agar-agar, were used, prepared in various ways. Milk and whey also were tried. Besides these preparations from the calf, other organic substances were employed, such as infusions of various vegetables, and solutions of organic salts on which other organisms were known to thrive. Eggs also were used in various

* "In artificial media it is a frequent experience to find organisms destroyed by the virulence of their own products, before all the food material adapted to their existence has been exhausted." . . . "Pathological Mycology." Section 1; Methods, p. 17. . . . "The products of the decomposition started and maintained by septic organisms . . . have a most detrimental influence on themselves, inhibiting their power of multiplication; in fact, after a certain amount of these products has accumulated, the organisms become arrested in their growth, and finally may be altogether killed." "Micro-organisms and Disease," Klein, p. 171.

ways. Newly-laid eggs were cleansed antiseptically—as regards the shell,—a small piece of the shell was broken, a capillary tube containing lymph was inserted into the albumen, and the lymph planted by heating the tube, the outer end of the tube being sealed and the lymph being forced into the egg by the expansion of the air in the tube. The albumen was also taken into watch glasses and was sometimes mixed with other substances.

Of all these soils the best were found to be for primary culture, potatoes, or veal soup with peptone thickened with agar; and for secondary cultivations, veal soup with cloth or marble. It was also found that the soil should be neutral or slightly alkaline.

The next point which falls to be considered was as to the temperature at which the cultivations should be made. In my earlier experiments the cultivations were made at the ordinary atmospheric temperature in summer, and in a room maintained at a moderately uniform temperature by means of an ordinary coal fire in winter. The growths were slow and somewhat uncertain. For the last three or four years I have used cultivating chambers, in which the specimens could be maintained for long periods at suitable uniform temperatures. Of these chambers I used two. They were made of galvanised iron. They had double walls (Plate XIV., Fig. I., *a* and *b*), between which water was contained, and one had in front a sliding window (*c*), composed of two sheets of glass with air between them; the other was closed on the top by a lid of metal, and was dark. They were heated by a Bunsen flame (*d*), the gas supplying which passed through a Reichardt's gas regulator (*e*), which dipped into the water, and which secured a uniform temperature. They were lined with felt. A minimum and maximum registering thermometer was kept inside each. In the one with glass front I had an arrangement for passing gases through the chamber or through individual flasks, which consisted of metal tubes (*f*) passing through the walls on each side. The temperatures which have been tried in these chambers have varied from 70° F. to 100° F. Temperatures from 70° F. to 80° F. are very satisfactory for primary cultivations, and from 90° F. to 98° F. for secondary. Cultivations have been maintained for weeks and sometimes months at uniform temperatures, varying only one or two degrees. The growths at these temperatures showed themselves speedily, and advanced rapidly. They were rather softer and less coloured than those grown at lower temperatures, and as a rule a larger number of initial spots arose from the

planting. The influence of air was also tested. This was done in various ways. *First*, test tubes and flasks containing various soils were inoculated with lymph and were hermetically sealed by drawing out and closing the neck in a Bunsen flame. *Second*, by planting the lymph into the deeper portions of the gelatine solution by means of a long capillary tube; or by planting on the surface of the gelatine, and then pouring over this surface some of the same gelatine soup cooled to near its solidifying point. *Third*, the lymph was planted in soup, and a layer of stearine or other oil or oily acid was poured on the surface so as to exclude air. *Fourth*, by means of double tubes passing into soup in the flasks, air was made to bubble through the liquid by means of an aspirator. It was found that in the absence of air, or with the limited quantity contained in the hermetically sealed vessels, little or no growth took place, that is to say, they require air for active growth; they are aerobic. An excess of air did not appear materially to assist the development. To test the effects of different gases on these organisms two plans were employed. *First*, flasks or test tubes (as were found for this purpose most convenient) were duly inoculated and plugged, and were then placed in a wire cage under the bell-jar of an air-pump (Fig. VIII.) Air was exhausted, the gas to be experimented with was then admitted. and the cultivations continued in the presence of these gases. *Second*, another plan adopted to test the effects of gases was as follows:—Flasks were employed which had two pieces of tubing (Fig. II.) themselves plugged with cotton wool passing through the cotton-wool plug of the flasks, one tube reaching to near the surface of the soil, and the other passing only a little way into the flask. The flask stands in the incubating chamber, the gas apparatus being attached by india-rubber tubing to one of the small pipes on the side of the chamber. This pipe is attached to the long dipping tube in the flask. The other tube of the flask is similarly connected with another small side pipe. The gas thus passes through the flask, coming into close contact with the growth, and passes through the other tube out of the chamber. In this way we avoid influencing by the gas the other cultivations going on alongside for comparison. Round the cotton-wool plug of the flask we may place melted paraffin, so as more effectively to enclose the gas. In this way we may connect a number of flasks, and pass the gas through the series. Various gases were employed in these ways to *test their* influence on the microbes. Although I have performed

many experiments on this subject, I do not consider them concluded, but so far as they go it may be said that under nitrogen there is practically no growth; that under oxygen they grow, but not with any luxuriance; and that under carbonic acid their growth is active, but not more so than with ordinary atmospheric air. The effects of light and darkness were also tested by using the two incubators already described—one admitting light by the glass front, and the other entirely dark. The microbes grew as well in the dark as in the light.

The next point to consider was—What lymph should be used as seed? I have tried calf lymph, vaccine scabs, and fresh humanized lymph, but I give the preference to the humanized, because the calf lymph was difficult and it was practically impossible to obtain the scabs free from extraneous organisms. The method of collecting the lymph and planting it is very important, as on this depends largely the success in obtaining pure cultivations. Newly-drawn capillary tubes, about 15 inches in length, are hermetically sealed in the flame at both ends, and are then placed in the sterilizing box and heated to 300° F. for an hour. A healthy child, on whose arm vaccine vesicles of the eighth day are well developed, is selected. The vesicles and the skin adjoining are well sponged with lint soaked in a solution of bi-chloride of mercury, 1 in 100. This thoroughly cleanses the skin and destroys any organisms which may exis on the surface. The vesicles are now thoroughly sponged with absolute alcohol, so as to remove the mercury, which of course would destroy any lymph with which it came into contact. The absolute alcohol speedily evaporates, leaving the surface of the vesicles clean and aseptic. The vesicles are punctured with a clean needle, which has just been sterilized by heating to redness in a flame and cooled by touching with absolute alcohol. The lymph immediately begins to exude. The two ends of one of the sterilized capillary tubes are broken off under sterilized cotton wool, which is kept wrapped round one end; the other end of the tube is dipped into the beads of the lymph on the arm, which of course pass into the tube by capillary attraction. About one minim is sufficient for each tube. The tube is now removed from the arm, the air in it is expanded by passing it through the flame. A piece of sterilized cotton is placed over the end containing the lymph, and the opposite end of the tube is closed by melting the glass in the flame. On the contained air cooling, the lymph passes

as closely as possible, a mass of brightly-glowing coal or coke. This brick reached all the way across the gas-fire, and it was generally seven or eight inches high, and about three-and-a-half inches in thickness. It consisted essentially of two portions. The posterior half had a plain, solid surface, where it was set against the anterior portion of the air-heating space, and the front portion of the brick was formed of the irregular fretwork previously referred to, its individual parts being separately moulded by hand out of soft, plastic clay. Along the bottom edge of the "burner brick" there was a series of openings, each of which was opposite to one of the Bunsen burner tubes. These openings were shown to communicate with numerous irregular passages, so that the upward progress of the current of hot gases might be as much baffled or interrupted as possible. When the "burner brick" was properly fashioned, and the gas-fire was going well, the lower portion of the brick should become incandescent, even to whiteness, while the upper portion was of a more or less bright red; and such a fire was one of the very best "make-believes" that had yet been brought under public notice.

NOTE.—The gas-fire described was designed for consuming about 36 cubic feet of gas per hour. Through the kindness of Messrs. R. & A. Main, a typical example of this invention was fitted up on the lecture table and shown in practical operation during the evening. Much interest in it was displayed by the members present.—J. M.

XXXIII.—*An Experimental Research on the Artificial Cultivation of Vaccine Lymph, with observations on the nature of Vaccine and the Immunity produced by Vaccinia.* By Neil Carmichael, M.D.

[Read before the Society, 19th January, 1887.]

Normal vaccine lymph is a colourless transparent liquid, in chemical composition resembling the plasma of blood, and containing solid particles of various kinds. It is rich in albuminous substances, and contains salts, mainly phosphates of alkalies and alkaline earths, which give to it a slightly alkaline reaction. Under the microscope the particles held in suspension are found to be leucocytes (white blood corpuscles, or pus cells), epithelial cells from the skin, large multinuclear cells, numerous irregular particles, probably the debris of cells, and micrococci. These micrococci* may be found free or variously grouped, not infrequently forming chains, but as a rule massed, without any evident system of grouping. They are minute colourless motionless transparent spherules, in diameter about the twenty-thousandth of an inch, and are probably vegetable and parasitic† in their nature. They multiply by fission, and when planted in a suitable soil, as in the skin of a child or a calf, they multiply with great rapidity. These micrococci are invariably present in vaccine lymph, humanized or calf, and no other organisms are found. It is now pretty generally conceded that these micrococci are the specific agents in vaccine lymph which produce vaccinia. Experiments by Chauveau,‡ Burdon Sanderson,§ and others, have demonstrated that the liquid portion of the vaccine lymph, that is to say, the vaccine lymph freed by filtration or deposit from its contained particles, does not produce vaccinia, and that the particles, on the other hand, are capable of producing the disease. But which amongst the particles produces the disease? We

* "Micro-organisms and Disease," Klein, p. 47. "Le Bactéries," Cornil and Babes, p. 535.

† Braidwood and Vacher.

‡ Comp. Rend. Acad. d. Sc., Paris, t. lxvi. 1868.

§ Report on "Intimate Pathology of Contagion."

cannot attribute the active agency to the leucocytes, because these are inflammatory products, and are fewest in the most active lymph; nor to the epithelial cells or the granular debris, because these are really necrosed particles, the products of the inflammatory and specific action within the vesicles, and, like the leucocytes, are least to be found in the purest and most active lymph. Nor can we attribute it to the large multinuclear cells which are few in number, which are evidently tissue cells proliferating, and which are few in active lymph; nor to blood cells or other adventitious particles. There remain, then, only the micrococci to which we can ascribe the active agency in the production of vaccinia. That this is so is supported by the following considerations:—*First*—They are invariably present in vaccine lymph; they are uniform in size and other characters; they are abundant in the purest and most active lymph. *Second*—They are the only living organisms found in vaccine lymph. *Third*—They multiply enormously when the lymph is planted on the calf or human subject, in the vaccinated tissues, and subsequently in the vesicles; and this active proliferation is coincident with the active development of vaccinia.* *Fourth*—They resemble organisms which are found in some other infectious diseases, such as erysipelas and pneumonia, which have been proved to be the specific factor in the production of these disorders. And so we are, I believe, justified in assuming that these micrococci are the active agents in the vaccine lymph which produce vaccinia. It is interesting to note that smallpox virus contains microbes almost, if not indeed absolutely identical, in appearance with those of vaccine lymph.†

When vaccine lymph is inserted into the skin of an infant, besides reproducing itself in increased quantity, it produces the specific disease vaccinia. This specific disease in some way modifies the condition of the subject for years, so that lymph subsequently planted in the skin will not develop and vaccinia cannot be produced. Besides this it is found that the vaccinated subject is much less susceptible to, or is entirely protected against, smallpox, so that the micrococci of vaccine lymph and smallpox are now incapable of developing on this soil. In what manner the development of vaccinia and the multiplication of the

* Braidwood and Vacher.

† Cornil and Babes. Warlomont's "Manual of Animal Vaccination," *page 3.* Klein, "Micro-organisms and Disease," p. 47.

microbes produce the protection or insusceptibility just considered is still unsettled. Various hypotheses* have been suggested. The first theory is that of exhaustion. It is assumed that the microbes entirely use up or destroy some material in the system which is necessary, that is to say, which constitutes the food or a necessary portion of the food of these organisms. Against this it may be stated :—*First*—That we do not know any such material; *Second*—That any normal constituent of the body, if removed, would in all probability be speedily renewed; and *Third*—That such microbes of disease as are familiarly known to cause insusceptibility to their own further growth in the protected subject, can be grown in infusions of the tissues of the protected subject, and in comparatively simple infusions. The second hypothesis is the so-called vital theory. This supposes that, on the microbes beginning to multiply in the system, a struggle for supremacy takes place between the tissue cells and the microbes, which, when the tissue cells are victorious, results in the cessation of the disease and an increase of vital energy, such as renders the tissues insusceptible to the further action of these microbes. This is poetical, but it has not much beyond this quality to recommend it. It is curious, besides, that the increased vital energy should not also enable the system to resist the attack of other infectious microbes. The third hypothesis is the antidotal theory. It is assumed that in the process of growth the microbes give to the system chemical products which are destructive, or at least inhibitive, to the organisms producing them. When yeast is planted in grape juice it multiplies, forming alcohol and carbonic acid, until the proportion of alcohol reaches 14 or 15 per cent. After this point no further growth of yeast cells takes place, because alcohol in this proportion is inhibitive to the growth of yeast, as it is in large proportion entirely destructive to these organisms. If the alcohol is driven off by heat, the liquid will again sustain the yeast plant, showing that the previous cessation of growth was due, not to something necessary for food having been removed from the liquid, but to something destructive having been added by the growing yeast. But this liquid, though it prevents the growth of yeast, is still capable of growing other very similar organisms, such as *mycoderma aceti*, which causes the acetic fermentation. The acetic acid formed by the growth

* "Manual of Animal Vaccination." Warlomont, p. 12. Klein, p. 185.

of *mycoderma aceti* acts towards this organism as does the alcohol toward yeast, arresting further growth, and, if in large proportion, destroying the organism which produced it. The same holds good with the lactic ferment, the butyric ferment, and others. The same also holds true of the cells of the higher organisms, including man. The secretion of the gastric cells, when in contact with these cells, restrains their further secretion.* It may indeed be looked upon as a general law of biology, that the chemical products of living organisms, when retained in contact with these organisms, check or arrest their functions or perhaps even destroy the organisms.† If then the chemical products of the growth of the vaccine micrococci pass into the circulation of the body and into the tissues, it is not hard to suppose that when a certain degree of saturation is produced the tissues will no longer support the life of the microbes, and so long as these products remain in the tissues the subject will be proof against the further development of vaccinia.

In vaccinating we have the choice of two kinds of lymph, calf and humanized.‡ It is objected to the use of humanized lymph, *First*—That it is inferior in potency and in protective power to calf lymph, and to the humanized lymph as first used by Jenner. It is supposed by cultivation in the human subject to have become so modified that it is less violent in action and produces a less degree of protection. *Second*—It is objected that there is great risk of transmission of disease from child to child with the lymph. This danger is, however, with care on the part of the operator, an exceedingly slight one, few instances being known in which the transmission of disease has been definitely proved. *Third*—It is objected that the supply of humanized lymph is unequal to the emergency of an epidemic of smallpox.

Against the use of calf lymph it is objected, *First*—That it is unnecessarily violent in its action, and it is not yet certain that it is of higher power in protecting against smallpox. The greater virulence of its action does not necessarily imply greater specific power, and it is well known that its infecting power to the human subject is less than that of humanized lymph, much greater care

* Klein, p. 171. "Micro-parasites in Disease." Preface, p. 12. Dr. Watson Cheyne.

† "Pathological Mycology." Woodhead and Hare, p. 17.

‡ "Vaccination" Article by Dr. Collie in Quain's "Dictionary of *Medicine*," p. 174. Warlomont. Seaton.

being necessary to secure successful vaccination with it. This lessened infective power may, however, be due simply to change of soil, and it does not necessarily imply lessened protective power. *Secondly*—It is objected that calf lymph may be the means of transmitting to the human subject the diseases of the calf, such as tubercle; and it is much more easy to select a healthy child than a healthy calf.

This being the present position of the question of vaccination, it suggests itself at once to us that if we can cultivate the microbes of vaccinia in some suitable soil which is harmless, and retain the infecting and protecting power, we meet all the objections raised to the use of calf or humanized lymph. We would have the certainty that no other disease was transmitted, and we would be able to produce lymph in unlimited quantity.

More than ten years ago I took up this line of inquiry, and have been since then more or less continuously engaged in the research, and, so far as I am aware, I was the first to make the attempt, and for many years was the only worker in this line. It was suggested to me *(a)* by the prediction of Sir Joseph Lister—whose class of Surgery I had the privilege of attending—"That all infectious diseases would be found to be due to living organisms;" *(b)* by the fact that Pasteur and Koch had proved that certain diseases, which they had specially studied, were due to these organisms, had cultivated these organisms outside the body, and had by these cultivations been able to reproduce the disease; and *(c)* also by the fact that I had been specially engaged in the study of vaccination.

In 1883 the Worshipful Company of Grocers of London offered a prize of £1,000 for the discovery of a "Method by which the vaccine contagium may be cultivated apart from the animal body, in some medium or media not otherwise zymotic; the method to be such that the contagium may by means of it be multiplied to an indefinite extent in successive generations, and that the product of any number of such generations shall (so far as can within the time be tested) prove itself of identical potency with standard vaccine lymph."* My experiments on the subject, which were begun seven years before the offer of this prize, have all along aimed at similar results, under conditions similar to those named. I have, however, not claimed the prize, as I have not been able,

* Grocers' Company advertisement.

nor, as yet, has any other, to fulfil all these conditions. Such results as I have obtained I propose to lay before you.

I do not propose to lay before you my experiments in a chronological order, or to tabulate them all, as that would only weary you with a long account of failures. It will best serve our purpose to sketch shortly the various methods employed, and to consider carefully such positive results as have been obtained. In beginning this investigation a number of preliminary points presented themselves for consideration. It was necessary to obtain the lymph and to cultivate it under such conditions as would secure that no organisms other than those of the lymph should gain access. To secure this,* it was necessary that all apparatus should be sterilized by heating or by steeping in some antiseptic solution, such as solution of bi-chloride of mercury, that the soil should be aseptic or should be disinfected by heat, and that the lymph should be collected and transferred to the soil in such a manner as to obviate or reduce to a minimum the danger of contamination with extraneous organisms. Test tubes and flasks, into which cultivating soil was to be placed, were plugged with cotton-wool stoppers, and were then placed in an iron box and heated to 300° F. for an hour or so, thoroughly to sterilize them. The glass cups and shades and the plates used for making the cultivations on potatoes were sterilized by steeping in a watery solution of bi-chloride of mercury, of strength 1 to 100. Fresh tissues and blood were taken from newly-killed animals under a carbolic acid spray, by means of sterilized instruments, into sterilized vessels, and immediately closed by sterilized wool plugs enclosed in gauze, if a large surface required to be covered. Eggs were taken, as fresh as possible, washed in an antiseptic solution, and wrapped in cotton wool which had been sterilized by steeping in an ethereal solution of carbolic acid and dried. White of egg was taken into a beaker with glass cover and glass sole-plate, which had been steeped in a solution of carbolic acid and heated so as to drive off the acid and leave them in an aseptic condition. Milk, whey, soups, and animal infusions of various kinds were boiled and received into sterilized flasks and test tubes, with sterilized cotton-wool plugs, and heated in steam to about 212° F. for an hour on three successive days. Potatoes were sterilized by thoroughly washing and brushing the skin, then steeping them for

* The methods were the same in principle, and frequently also in detail, *as those* described by Klein, Woodhead, Hare, Koch, etc.

an hour in a solution of bi-chloride of mercury, and finally steaming them for half an hour at 212° F. These and many other precautions were adopted to render it certain that the apparatus and the soil used were themselves free from organisms. It may perhaps be doubted if such precautions were necessary. That they were, is, I think, evident from a few considerations. All successful cultivations, known technically as pure cultivations,* of other infecting organisms have been made with somewhat similar precautions, and all who have made these investigations insist on the necessity of such care. And while it is the case that the vaccine virus can grow and multiply in the human body along with other infective organisms,† and perhaps outside the body may be able to grow mixed with other organisms, what we wish to obtain is a cultivation of the organisms contained in vaccine lymph, in a pure condition, unmixed with any other organisms, so that we may be certain that the microbes cultivated are the actual development of those in the lymph, and are uninjured by admixture of any other form of life.‡

The next point which presents itself to us is whether the lymph should be planted on a free surface or immersed in a liquid. In the ordinary process of vaccination the lymph is planted locally on the arm of the child, or near the udder of the calf. In my earlier experiments I immersed the lymph in liquids. So treated, the micrococci rapidly multiplied, but I did not find that they retained their infecting power. In my later experiments, having seen an account of Koch's gelatine process of cultivating organisms, I adopted various modes of planting on a fixed surface, as on potatoes (Plate XIV., Fig. V.), turnips, and animal tissues, and on soups and other organic fluids thickened with gelatine or Japanese isinglass, known as agar-agar (Plate XIV., Figs. VI. and VII.), which does not liquefy at the highest temperature necessary for cultivation. It was found that on these the growths, though active at first, especially with the secondary cultivations, gradually became slower and finally stopped long before the surface of the soil was covered. I concluded that either the suitable nutriment in the neighbourhood was used

* Koch in "Micro-organisms and Disease," p. 32 *et seq.*

† Vaccinia may develop in presence of syphilis, measles, and other diseases. It may develop even along with smallpox, if inserted during the period of incubation of the latter.

‡ See Koch on pure cultivations in "The investigation of pathogenic organisms," as translated in "Micro-parasites in Disease," by Cheyne.

up, which, however, was unlikely, or that the neighbouring soil had become saturated with the chemical products of the organisms, and had so become in a measure protected or insusceptible as regards further growth of these organisms.* I adopted various plans of planting the lymph on a fixed surface to which nutrient fluid was freely supplied. I suspended into the liquid, in test tube and flasks (Plate XIV., Fig. III.), pieces of linen and flannel held in position by platinum wires which passed through the cotton-wool plug. The lymph was planted on the cloth above the liquid, the lower end of the cloth by capillary attraction drawing up the nutriment and carrying away the chemical products. I also adopted the method, which I found more satisfactory, of placing a piece of marble in the liquid in the flask (Plate XIV., Fig. IV.), the marble being large enough to reach above the surface of the liquid. The lymph was planted on the marble, and nutriment was supplied and the chemical products were removed by the capillary movements of the liquid on the marble. This plan had the additional advantage that it neutralized any acid which might be formed in the preparation of the nutrient fluid or in the growth of the organisms. As to the kind of soil to be employed, it seems desirable to approximate as closely as possible to the nature of the tissues of the calf on which we know that vaccine thrives. Portions of the heart, liver, brain, and other organs of the calf, were tried. Calf blood and serum also were employed. The eyes of calves were also used, the lymph being inserted into the aqueous and vitreous humors, the eye being maintained in an antiseptic condition. Also, the vitreous and aqueous humors were taken into sterilized watch glasses and lymph planted on them. Infusions of veal alone, or with peptone and agar-agar, were used, prepared in various ways. Milk and whey also were tried. Besides these preparations from the calf, other organic substances were employed, such as infusions of various vegetables, and solutions of organic salts on which other organisms were known to thrive. Eggs also were used in various

* "In artificial media it is a frequent experience to find organisms destroyed by the virulence of their own products, before all the food material adapted to their existence has been exhausted." . . . "Pathological Mycology." Section 1; Methods, p. 17. . . . "The products of the decomposition started and maintained by septic organisms . . . have a most detrimental influence on themselves, inhibiting their power of multiplication; in fact, after a certain amount of these products has accumulated, the organisms become arrested in their growth, and finally may be altogether killed." "Micro-organisms and Disease," Klein, p. 171.

ways. Newly-laid eggs were cleansed antiseptically—as regards the shell,—a small piece of the shell was broken, a capillary tube containing lymph was inserted into the albumen, and the lymph planted by heating the tube, the outer end of the tube being sealed and the lymph being forced into the egg by the expansion of the air in the tube. The albumen was also taken into watch glasses and was sometimes mixed with other substances.

Of all these soils the best were found to be for primary culture, potatoes, or veal soup with peptone thickened with agar; and for secondary cultivations, veal soup with cloth or marble. It was also found that the soil should be neutral or slightly alkaline.

The next point which falls to be considered was as to the temperature at which the cultivations should be made. In my earlier experiments the cultivations were made at the ordinary atmospheric temperature in summer, and in a room maintained at a moderately uniform temperature by means of an ordinary coal fire in winter. The growths were slow and somewhat uncertain. For the last three or four years I have used cultivating chambers, in which the specimens could be maintained for long periods at suitable uniform temperatures. Of these chambers I used two. They were made of galvanised iron. They had double walls (Plate XIV., Fig. I., *a* and *b*), between which water was contained, and one had in front a sliding window (*c*), composed of two sheets of glass with air between them; the other was closed on the top by a lid of metal, and was dark. They were heated by a Bunsen flame (*d*), the gas supplying which passed through a Reichardt's gas regulator (*e*), which dipped into the water, and which secured a uniform temperature. They were lined with felt. A minimum and maximum registering thermometer was kept inside each. In the one with glass front I had an arrangement for passing gases through the chamber or through individual flasks, which consisted of metal tubes (*f*) passing through the walls on each side. The temperatures which have been tried in these chambers have varied from 70° F. to 100° F. Temperatures from 70° F. to 80° F. are very satisfactory for primary cultivations, and from 90° F. to 98° F. for secondary. Cultivations have been maintained for weeks and sometimes months at uniform temperatures, varying only one or two degrees. The growths at these temperatures showed themselves speedily, and advanced rapidly. They were rather softer and less coloured than those grown at lower temperatures, and as a rule a larger number of initial spots arose from the

planting. The influence of air was also tested. This was done in various ways. *First*, test tubes and flasks containing various soils were inoculated with lymph and were hermetically sealed by drawing out and closing the neck in a Bunsen flame. *Second*, by planting the lymph into the deeper portions of the gelatine solution by means of a long capillary tube; or by planting on the surface of the gelatine, and then pouring over this surface some of the same gelatine soup cooled to near its solidifying point. *Third*, the lymph was planted in soup, and a layer of stearine or other oil or oily acid was poured on the surface so as to exclude air. *Fourth*, by means of double tubes passing into soup in the flasks, air was made to bubble through the liquid by means of an aspirator. It was found that in the absence of air, or with the limited quantity contained in the hermetically sealed vessels, little or no growth took place, that is to say, they require air for active growth; they are aerobic. An excess of air did not appear materially to assist the development. To test the effects of different gases on these organisms two plans were employed. *First*, flasks or test tubes (as were found for this purpose most convenient) were duly inoculated and plugged, and were then placed in a wire cage under the bell-jar of an air-pump (Fig. VIII.) Air was exhausted, the gas to be experimented with was then admitted, and the cultivations continued in the presence of these gases. *Second*, another plan adopted to test the effects of gases was as follows:—Flasks were employed which had two pieces of tubing (Fig. II.) themselves plugged with cotton wool passing through the cotton-wool plug of the flasks, one tube reaching to near the surface of the soil, and the other passing only a little way into the flask. The flask stands in the incubating chamber, the gas apparatus being attached by india-rubber tubing to one of the small pipes on the side of the chamber. This pipe is attached to the long dipping tube in the flask. The other tube of the flask is similarly connected with another small side pipe. The gas thus passes through the flask, coming into close contact with the growth, and passes through the other tube out of the chamber. In this way we avoid influencing by the gas the other cultivations going on alongside for comparison. Round the cotton-wool plug of the flask we may place melted paraffin, so as more effectively to enclose the gas. In this way we may connect a number of flasks, and pass the gas through the series. Various gases were employed in these ways to test their influence on the microbes. Although I have performed

many experiments on this subject, I do not consider them concluded, but so far as they go it may be said that under nitrogen there is practically no growth; that under oxygen they grow, but not with any luxuriance; and that under carbonic acid their growth is active, but not more so than with ordinary atmospheric air. The effects of light and darkness were also tested by using the two incubators already described—one admitting light by the glass front, and the other entirely dark. The microbes grew as well in the dark as in the light.

The next point to consider was—What lymph should be used as seed? I have tried calf lymph, vaccine scabs, and fresh humanized lymph, but I give the preference to the humanized, because the calf lymph was difficult and it was practically impossible to obtain the scabs free from extraneous organisms. The method of collecting the lymph and planting it is very important, as on this depends largely the success in obtaining pure cultivations. Newly-drawn capillary tubes, about 15 inches in length, are hermetically sealed in the flame at both ends, and are then placed in the sterilizing box and heated to 300° F. for an hour. A healthy child, on whose arm vaccine vesicles of the eighth day are well developed, is selected. The vesicles and the skin adjoining are well sponged with lint soaked in a solution of bi-chloride of mercury, 1 in 100. This thoroughly cleanses the skin and destroys any organisms which may exis on the surface. The vesicles are now thoroughly sponged with absolute alcohol, so as to remove the mercury, which of course would destroy any lymph with which it came into contact. The absolute alcohol speedily evaporates, leaving the surface of the vesicles clean and aseptic. The vesicles are punctured with a clean needle, which has just been sterilized by heating to redness in a flame and cooled by touching with absolute alcohol. The lymph immediately begins to exude. The two ends of one of the sterilized capillary tubes are broken off under sterilized cotton wool, which is kept wrapped round one end; the other end of the tube is dipped into the beads of the lymph on the arm, which of course pass into the tube by capillary attraction. About one minim is sufficient for each tube. The tube is now removed from the arm, the air in it is expanded by passing it through the flame. A piece of sterilized cotton is placed over the end containing the lymph, and the opposite end of the tube is closed by melting the glass in the flame. On the contained air cooling, the lymph passes

along the tube, the air which enters after it being filtered through the wool. This end is now sealed in the same manner as the other. By this means we obtain pure lymph, uncontaminated by anything on the arm or in uncleansed tubes. And, by way of parenthesis, permit me to say that I strongly urge this method of collecting and storing lymph for ordinary use, and especially for lymph which is intended to be kept long or sent abroad. It is well known that lymph, as ordinarily collected and stored, deteriorates in a short time and is then usually found to contain bacteria. Such long tubes as I have mentioned are not required for ordinary use, a length of five to six inches being sufficient.

Having obtained the pure lymph, we have now to plant it so as to avoid risk of contamination. The plan which I have adopted is as follows:—Heat the long capillary tube containing the lymph at about the middle, and bend to an angle of 60 or 70 degrees, then cleanse externally that limb of the tube which contains the lymph by sponging it with bi-chloride of mercury, then with absolute alcohol; pass rapidly through the flame to burn off the alcohol; break a small piece off the end of the tube on the limb which does not contain the lymph, under sterilized wool, then break a small piece off the end which does contain the lymph, also under sterilized wool. Now loosen the cotton-wool plug of the flask, very slightly withdrawing it, pass in the limb of the capillary tube containing the lymph till it touches the surface of the soil; heat the outer limb of the tube, sealing the end of it, and expanding the air contained in it. This drives the lymph out of the other limb, and plants it on the soil. Withdraw the tube and tighten the cotton-wool plug. In this process the risk of accidental contamination is exceedingly slight.

In making secondary cultivations for solid growths, the culture is lifted from the potato or agar on a fine glass rod or platinum wire, and inoculated on the new soil with similar precautions. In making secondary cultivations from liquid cultures, the lymph is lifted in the capillary tubes and similarly transferred.

One important point in these experiments was to ensure, as already referred to, that the soil was pure. For this purpose the flasks, with soil ready for planting, were kept in an incubator for a week or more, in which period, if any organisms had been present, they would have manifested themselves.

Having considered the conditions and described the processes of the cultivations, we now come to the results. These have been

by no means all that were desired, but such as they are we give them.

On the surface of the potatoes and on the gelatine soil, the lymph produces a growth of a smooth, sometimes undulated (Plate XIII., Fig. I.) mass, irregular and sometimes dentate (Fig. II.) at its edges, of a pearly white, yellow, salmon, orange, or almost red colour. In the gelatine it pushes slightly below the surface, but not to a great extent. It does not liquefy the gelatine. On potatoes the primary growths are frequently like toadstools. With temperatures of 50° F. or 60° F., the growths are slow in appearing, ten days to six weeks elapsing before any sign is to be detected. In this case the first appearance is usually a firm-looking orange-coloured minute spot, less than a pin-head in size, somewhere within the planted area. This gradually grows and spreads over the surface, covering perhaps a square inch or so after a few weeks. Amongst the mass will frequently be found small white growths, differing from the rest only in colour. When grown at from 90° F. to 100° F., the primary growths may appear in from one to three or four days, or sometimes within 12 hours. In this case the first growth may coincide with the whole area which has been planted. In the former case the great mass of the microbes fail to germinate, one or two spots only showing growth as a rule, and sometimes the culture entirely failing; at the higher temperatures 20, 50, or more spots of growth may be discernible at once, or the whole of the planted surface may be covered with a mass. These spots soon coalesce and form a mass softer and usually whiter than the slower growths. They spread rapidly. Under the microscope these masses are found to consist of micrococci, in masses, chains, and sometimes, but rarely, otherwise grouped. They are about the $\frac{1}{20000}$th of an inch in diameter, and are quite indistinguishable from the micrococci of vaccine lymph. If a portion of the edge of this growth, at a distance from the originally planted lymph, is lifted on a piece of sterilized glass or platinum wire, and planted on fresh soil with precautions similar to those adopted in the primary plantings, it is found that growth is evidenced much more speedily than in the primary cultures, a few hours serving to show its activity; and it continues to advance much more rapidly. It would seem as if the first awakening of vital activity on the new soil was slow, but that having once begun to grow on it, the organisms speedily become adapted to their new environment: we may say that they have become naturalised.

When the fresh lymph was planted on marble, linen, or flannel dipping into the nutrient fluid, a similar growth took place; but it more frequently failed in these cases than on a dry soil. The growth, when it did take place, was much softer, and tended even to flow, and besides the growth on the marble, linen, or flannel, there was found diffused through the liquid, and lying on the bottom of the flask, a white powdery-looking mass. These growths and the powdery mass were also capable of secondary cultivation, and were found to consist of the same micrococci as the dry solid cultures. On these immersed solids the secondary growths were much more certain and active than the primary. When the fresh lymph was immersed in liquid it frequently failed to grow, and when it did succeed a slight opacity resulted, and a white powdery mass was found on the bottom of the flask. This also was composed of the same micrococci. Secondary cultures were more certain and more rapid in liquid than were the primary, but less so than on marble and cloth. They do not go on growing indefinitely, but stop after a time.

The growth after each of these plans could be reproduced in the same soil by secondary cultivation, or could be made to grow by transference to one of the other soils. They were mutually interchangeable, and microscopically they were identical Here I may mention that sometimes, notwithstanding the exercise of the utmost care, contamination did take place. This, however, was not at all frequent, and when it did take place it was easily detected by the naked-eye and microscopical appearances. The naked-eye appearances even, after any such contaminations as I have seen, are entirely unlike the naked-eye appearances of vaccine cultures.

We now come to the crucial test of the inquiry. Do these cultivated micrococci produce vaccinia? In the first case, being uncertain whether these microbes were harmless or hurtful, I did not feel at liberty to try them on children. My first experiments on this point were made upon myself in 1878. I vaccinated myself repeatedly with these products. They produced on me no effect, locally or otherwise. That they did not produce vaccinia did not surprise me, as I have been so thoroughly vaccinated and re-vaccinated as to have become a very unsuitable soil. These experiments, however, satisfied me that there was no danger in vaccinating with this material. I also tried these cultures on various animals, including calves. In most instances no positive

result followed. In some, papules were formed, which subsequently became vesicular. These, however, did not follow the normal course of vaccinia in the calf. On the sixth or seventh day papules appeared, which continued to enlarge. On the twelfth day the scars of the incisions were surrounded by a vesicular ring, which, on being opened and pressed, gave out a viscid opaque fluid, which I collected. With this liquid I vaccinated four children, but without result. It did not produce vaccinia. I then proceeded to vaccinate children with primary and secondary cultivations, and I considered it best to vaccinate the children with these cultures alone, and not at the same time with ordinary vaccine lymph, so as to obtain perfectly certain results. In performing these vaccinations I used a new lancet, which had not before been used, and which I kept exclusively for this purpose, so that there might be no risk of its retaining ordinary vaccine lymph. My first experiments in producing vaccine with artificial cultures were for some years unsuccessful. The culture was then made in liquid. Since I began to cultivate on dry soil, and especially since I began to make the secondary cultivations on cloth and marble, suspended in nutrient liquid, so as to expose the growth to the air, and supply them abundantly with nutriment, my results have been more successful. My previous failures I need not enumerate. Out of a large number of such vaccinations performed with primary and secondary cultivations, I found (1) that most failed entirely to produce any results; that (2) a considerable number produced imperfect vesicles; and (3) that some produced perfectly normal vaccinia. Those children on whom no result was produced, or who had imperfect vesicles, were subsequently vaccinated successfully with ordinary vaccine lymph. The normal vesicles which were produced by the vaccination with these cultures were *perfectly normal* as to their course and character, and were altogether indistinguishable from ordinarily produced vaccinia. These vesicles were found to yield lymph which also produced vaccinia, and which was in all respects like ordinary vaccine lymph.

Since my first successful vaccination with such cultures, which was made in December, 1885, I have vaccinated 96 children with these materials. Out of this number 10 were entirely successful, 20 to 25 produced abortive vesicles, which developed rapidly, and which rapidly burst, leaving a scab; the rest produced no result. Of these 10 successful vaccinations, 2 were from primary cultures on the veal soup with agar, 2 were secondary cultivations

on linen with veal soup, and 6 were secondary cultivations on marble in veal soup. The 2 successful cases from the linen cultures were 2 out of 20 attempts; the 2 on the gelatine soup were 2 out of 4; and the 6 on marble were 6 out of 51. The cultures on agar were, therefore, the most successful; but as these were primary cultures, and were of slow growth, they were not considered so satisfactory. The cultures on marble, being secondary cultivations and growing rapidly, were considered, on the whole, the most satisfactory which had been obtained. The white spots mentioned, as seen amongst the coloured growths when planted on marble and liquid, showed no difference in any respect from the coloured growths, microscopically, or in producing vaccinia.

Such is a brief statement of the actual results. How are we to interpret these results? *First*—All these cultures consisted of micrococci indistinguishable from those of ordinary vaccine lymph by microscopic examinations. *Second*—There were found in these cultures no other organisms. *Third*—These micrococci came from the lymph, as the sterilization of soil and apparatus and the modes of collecting and planting the lymph practically secured freedom from accidental contamination. We may, therefore, conclude that these micrococci are the direct progeny of the micrococci of vaccine lymph—that is to say, of the only organisms which the lymph is known to contain. But how is it that, if these organisms are indistinguishable from those of ordinary vaccine lymph, and are their actual progeny, they do not invariably produce a similar development of vaccinia? To this it may be answered, either (*a*) that the micrococci of vaccine lymph are not the true infecting agents, or (*b*) that the processes of artificial cultivation have modified the properties of the organisms.* But we have already seen that there is quite sufficient reason to assume that these are the active infecting particles, and besides, the fact that they have produced in some cases, as already mentioned, perfect vaccinia, entirely negatives this supposition.

* Pasteur on the "Attenuation of the Virus of Fowl Cholera" by his method of cultivation, says—"I would not dare to affirm that some morphological correspondences do not exist between the parasite and the various degrees of virulence which it presents, but I must admit that up to the present time I have been unable to perceive them, and that if such really exist, the eye armed with the microscope is prevented from perceiving them by the exceeding smallness of the virus. For all degrees of *virulence* the cultivations are alike." "Micro-organisms and Disease," p. 555.

The second explanation—namely, that cultivation in a new environment has modified the properties of the lymph to such an extent that its infecting power towards the human soil has been very greatly lowered seems much more natural, and is supported by numerous considerations. *First*, we do know that vaccine lymph is modified in its infecting power by change of soil. Calf lymph is more infective to the calf than to the child; applied to the child it requires more careful insertion in the skin to produce success than is required for humanized lymph.* The secondary cultivation of the calf lymph on the child is more infective than the original calf lymph, and so we perceive that change of soil *does* modify the infectivity of the lymph. *Second*, it is found that cultivation on new soils has a modifying influence on the properties of other infecting organisms. Pasteur, in his experiments on chicken-cholera,† found that by modifying the conditions of cultivation he could attenuate the force of the virus so as to secure a greatly modified form of the disease. So is it with anthrax. And it is interesting to note that Ceely found that when cows were successfully inoculated with smallpox lymph, cowpox resulted, and that when the lymph from this cowpox was inserted into the arms of children it produced vaccinia, and the eruption never approached in appearance to the smallpox eruption. Smallpox of man conveyed to the cow produced cowpox, but the cowpox thus induced re-transferred to man is as incapable as the natural cowpox itself of producing infectious smallpox. We see, then, that it is the case that change of soil modifies the properties of the organisms cultivated. *Third*, the artificial cultures of the lymph show modification in respect that the secondary cultures grow much more speedily and rapidly than the primary on the same soil. In adapting themselves to the new soil they become naturalised, and to this soil they are more infective. *Fourth*, the chemical products of the growth continuing to act on the micrococci in the dry soil or in the liquid, when present in a large proportion, may lower the infecting power of the organisms, as alcohol does

* In a circular issued by the National Vaccine Establishment, and signed by Dr. George Buchanan, it is stated of calf lymph "that such lymph does not 'take' with the same degree of certainty as humanized lymph:" that "two large points are needed for the vaccination of a single child"—showing lessened infectivity, and that "the course of the early vaccinations of a series is not so regular as with humanized lymph,"—showing that it is less fitted to develop normally in the human system than lymph which has become modified by humanization.

† "Micro-parasites in Disease." Cheyne, p. 551.

that of yeast. *Fifth*, the different susceptibilities of different children to vaccinia may account for the cultures proving ineffectual in producing vaccinia in many, and succeeding in a few. It may be argued, however, that the success was due to the fact that the cultures used were only a dilution of the original humanized lymph, and that some particles of this original material produced the vaccinia. To this the reply is, that when primary cultures in solids were employed, a portion of the edge of the growth at a distance from the part originally planted was employed. Most of the successes (8 out of 10) were obtained from secondary cultivations, in which the dilution, if such it was, must have been about one in ten thousand, and in which it was practically impossible for any of the original lymph to be present. And, besides this, the character of the successful results seems to point to the fact that the success was due to the special susceptibility of some children. When the same culture of micrococci was inoculated on a number of children, it entirely failed in most, but when it did succeed, it succeeded perfectly, the whole, or nearly the whole, of the punctures producing normal vesicles, which is more in harmony with the supposition of different susceptibilities than with the idea of the original particles being diluted, in which case we would have expected an occasional successful puncture on many rather than an entirely successful vaccination of a few. And here, again, the experience of Ceely throws light on this point. Ceely found that smallpox inoculated in cows succeeded in about one case in twelve, and Badcock found success in about seven per cent. In these cases the material employed, being smallpox matter was certainly not a dilute form of virus, and its success in a few cases, and failure in many, was clearly due to difference in susceptibility of the animals, and to the fact that to these animals this material had a low infecting power.

At this point we may venture an explanation of the abortive vesicles which in about 25 of the 96 cases were produced by the cultures. These irritative vesicles were the products of cultures which had been continued for from two to six weeks, and in which there was presumably a maximum of the chemical products of the growth of the organisms; and in connection with this may be stated an observation which I have frequently made. On potato cultures, primary or secondary, rapid or slow, which have stood for a long period, and which have ceased, or almost ceased, to grow, there is usually to be seen a dark discoloration of the potato, in

the form of a ring extending from an eighth of an inch to half an inch round the growth, most marked at the lower side of the growth, if the potato is in an inclined position. This is probably a soaking of the potato with the chemical products of the organism, and is the cause of the arrest of growth. In gelatine growths, especially in test tubes, a greenish discoloration frequently extends downwards into the gelatine for half an inch or more. This is probably of the same nature.

The hastily-developed vesicles already mentioned were probably due to an excess of irritating matter, perhaps the chemical products of the growth of the micrococci, which caused local irritation, and which lowered the vitality of the organisms. No protection was afforded by these vesicles, as subsequent vaccination with ordinary lymph was successful in all these cases. What then, is the outcome of this investigation?

First—We have succeeded in cultivating the vaccine contagium in the form of a crop of micrococci, the progeny of the micrococci of ordinary vaccine lymph.

Second—We have found that its failure in ninety per cent. of the cases proves it to be of lessened infective power and for purposes of general vaccination entirely unsuitable. It is of lessened infective power, but not necessarily, when it does succeed, of lessened protective power. It is not, I think, a truly attenuated lymph, because when it does succeed its success is perfect. It is lymph which, by naturalization in a new soil, has become less infective, that is to say, less ready to germinate in the old.

Third—We have succeeded in producing vaccinia on a number of children (ten per cent. of the cases), apparently susceptible, in a special degree, by inoculation of these cultures.

Fourth—These occasional successes serve as a fresh starting point for the renewal of lymph, enabling us not certainly to obtain a sufficient supply for general purposes of vaccination, but yet enabling us, in a soil not otherwise zymotic, to cultivate the contagium of vaccine lymph, and so to secure a fresh, untainted renewal of our lymph. Does this end the inquiry? By no means, or you would feel with me that the labour had been almost in vain.

What I have laid before you will, I hope, serve as stepping-stones to others and to myself, by which we may rise to more successful results. What is now required is to find some new mode of cultivation, or some modification of those enumerated—some adjustment of the environment, which will maintain the

infective power of the original lymph, or augment that of the cultures. But, before concluding, I have one suggestion to make. It is now held by many competent authorities that cowpox and vaccinia are modified derivatives of human smallpox. We have seen that the microbes of smallpox virus and of vaccine lymph are indistinguishable, and we know that much of the lymph at present in use is the direct outcome of the original inoculation of cows with smallpox matter made by Ceely. Is it not, then, the case that the change of soil has produced on the organisms a change much like that which Pasteur produced by attenuating the virus of chicken-cholera? If so, should not our starting point in attempting to cultivate these microbes be the micrococci of small-pox? and should we not seek to reduce these by such modes of cultivation as will attenuate them, so perhaps getting something nearer to the identical potency of vaccine lymph? This suggestion, which I make with all caution and reserve, may merit further consideration.

DESCRIPTION OF PLATES.

PLATE XIII.

CULTIVATIONS OF VACCINE MICROCOCCI ON GELATINE.

Fig. I.—Primary culture, slow of growth, with undulated border, showing mode of spreading.

Fig. II.—Similar growth with dentate edges, growing rather more rapidly.

Fig. III.—Secondary cultures, more fluid, growing and spreading much more rapidly.

Fig. IV.—Same as last.

Fig. V.—Primary cultures, showing six points from which the growths spread; of slow growth and of moderately firm consistency.

PLATE XIV.

Fig. I.—Incubator, made of galvanised sheet iron.

(a) and *(b)* Walls between which water is contained.

(c) Glass front composed of two plates of glass slightly apart. This window is suspended by a weight working over wheels, and so can be readily raised for inspection of preparations. It is shown raised in plate.

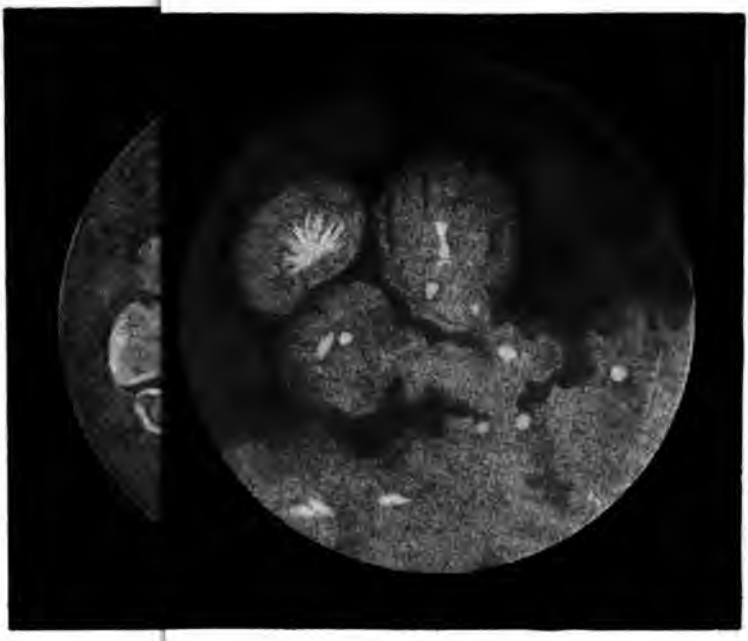


FIG. IV.

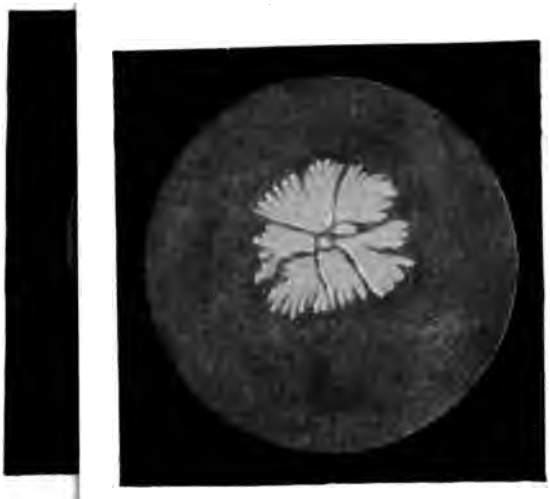
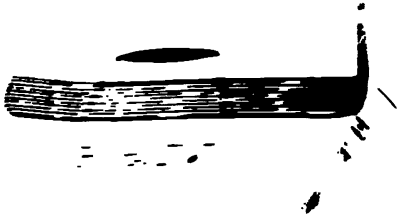


FIG. II



lymph proved successful. I continued to vaccinate with lymph cultivated in the same manner, and also under modified conditions, with the results stated in the text and shortly exhibited here :—

No. of Vacs.	Soils.		Microscopical Appearances.	Failure.	Success.
	Liquid.	Solid.			
20	Cloth (Plate XIV., Fig. III.) Veal tea + peptones, neutral or slightly acid or alkaline in reaction.		Micrococci rapidly multiplying on cloth, and in liquid, and at bottom of liquid.	18	2
51	Marble (Plate XIV., Fig. IV.) Same nutriment.		Ditto.	55	6
4		Veal tea + peptones + agar. Neutral or faintly acid or alkaline. (Plate XIV., Fig. VI.) These were primary cultivations.	Ditto.	2	2
2	Same liquid, in potash bulb; through air had been aspirated for seven days.		Ditto.	2	0
2	Same liquid, with layer of oil on top so as to exclude air.		Ditto.	2	0
11		Same soil as above + glycerine.		2	0
4		Same soil + chalk.		4	0
2	Sponge, with same liquid.			2	0

XXXIV.—*Automatic Electrical Lighting of Trains.*

By Thomas P. Carswell, C.E.

[Read before the Society, 13th April, 1887.]

There are three methods of train-lighting in use—namely, by oil, gas, and electricity. As this paper is only intended to deal with the latter, the first two systems will be passed over. The amount of light from each is in favour of gas as against oil, and of electricity as against gas. Incandescent lamps only are used in train-lighting by electricity, the arc light not being suitable. In using the incandescent lamps they are placed in each compartment, and generally take the place of the oil or roof lamp. There have been three practical applications of train-lighting by electricity. In the first two the roof lamps are replaced by incandescent lamps, while in the third case they have not been interfered with. The first method is still in use, the second has been abandoned, and the third is just being tried. Perhaps it will be better to give a short description of each, beginning with the first method.

In 1883 Messrs. Stroudley and Houghton took out a patent for lighting the Pullman train on the Brighton line. A small dynamo was placed in the guard's van, driven from shafting fixed under the floor, and the shafting was driven direct from the axle of one pair of wheels by means of a belt. The dynamo had patent reversible brushes to suit running of train in either direction, and was so arranged that the circuit was not closed till the train was running at a certain speed. The dynamo then charged a set of accumulators, also placed in the van, and weighing about 5 tons. The oil lamps were replaced by two 10 candle-power incandescent lamps in each compartment, connected by two main leads or wires to the accumulators. Flexible wires and brass couplings were used for connecting the carriages together.

By this means enough electricity was stored up to light the lamps when the train was at a stand, and it was only in the event of having to disconnect the train that the lamps were not lit. This system has been extended on this line, and seems to be working very well, but I cannot speak as to the cost of maintaining it. The lighting of the whole of the lamps is done by the guard, there

being a switch in his van so that they are under his control. Of course, in the event of one of the connections between the carriages giving way, the whole of the lights would go out.

The second method had two different arrangements—accumulators being used in one and not in the other, and the guard controlling the lighting of the lamps of the whole train as before.

In reference to the first arrangement, it may be stated that during the year 1884, on the Great Eastern Railway, and also on the Great Northern, incandescent lamps were used, the same as on the Brighton line, the carriages being connected together in the same way. Accumulators were also used, but these were placed at the ends of, or under, each carriage, and were charged by a small dynamo, fixed on the top of the locomotive boiler and driven by a high-speed engine. By this means the lamps were lit although the locomotive was not attached to the train, but owing to the difficulty in getting at the accumulators, and the attention they required, as well as the difficulty in keeping the connection between the carriages clean when the trains were broken up or shunted, both companies have given up this method entirely.

The following remarks apply to the second arrangement. During the year 1885 the Lancashire and Yorkshire Railway Company had some trains fitted in the same way, but no accumulators were used. There was considerable difficulty in keeping the speed of the dynamo constant, owing to variation of steam pressure, while the connections between the carriages were troublesome. The light, however, was satisfactory, but the extra cost and the benefits derived from its use did not warrant an extension of the system; and latterly it, too, was done away with altogether.

What I propose to speak of as the third method (patented 17th May, 1886) is that which is now being tried for the first time, I believe, on the Glasgow City and District Railway. Inasmuch as incandescent lamps are fixed in each compartment of the railway carriages, this and the other two methods of lighting spoken of have at least one feature in common.

On the City and District Railway the circumstances under which the light is required are entirely different from almost all others, as it is specially required during the day and while the trains are in the tunnels only. These trains run in the open air the greater part of their journey, but have to pass through the tunnels *from* three to fifteen times daily; or, in other words, they are,

on an average, somewhat over an hour in darkness. The arrangement for lighting each train as it enters the tunnel is as follows:—

A centre or third rail has been laid down from one end of the tunnel to the other, but is omitted in the open air. It is formed of ordinary ⊤ iron, and is inverted and laid on insulators or supports, so that it stands 4 or 5 inches higher than the ordinary rail. It is jointed together by small angle irons with four bolts, there being a small strip of sheet copper between the two to help the contact. The holes in it are oval so as to admit of expansion and contraction, and it is held in position by iron cotter pins, which pass through the sides of the jaws or supports. At each end of the tunnel, this centre rail or inverted ⊤ iron is bent down to the level of the ordinary rails so as to form an inclined plane. (Plate XV., Figs. 6 and 7.)

The insulators or supports which are used are made of glazed fire-clay, and have the central part or stem isolated from the base. The stem has two slots in it, one to receive the ⊤ iron, and the other for the cotter or split pin to pass through. A small piece of roofing felt soaked in oil is laid in the slot on which the ⊤ iron rests. The lower part or base is made in the form of a trough, which is filled with oil to help the insulation, and is fastened to the sleepers by means of two coach screws.

By this method of fixing the centre rail, it is always kept at the same height above the ordinary rails, and if the latter are raised the former is also raised, as it rises with the sleeper. The supports are fixed about 5 feet apart, and as far as can be seen they stand very well.

Two contact-makers or pulleys (Figs. 2, 4, and 7) are fixed to the framing of each carriage, at a height to correspond with that of the centre rail. Only one is required, but it is found that two give a steadier light, and where there are junctions to pass over; both are required to maintain the connection. These pulleys are made of crucible cast steel, and are 15 inches in diameter. They are hung on a centre, so as to move in horizontal direction, and have spiral springs on the top of the axle box, which allow them to rise vertically 3 or 4 inches. Two side flat springs are fixed on the hanger or jaw in which the pulley works, in order to keep it in a vertical position.

The current of electricity for lighting the lamps is derived from a large Crompton compound-wound self-regulating dynamo, having a potential at the terminals of 110 volts. This dynamo

is always kept running, the positive lead being connected to the centre rail, and the negative lead to the ordinary rails. It is driven by the same engine as is used for lighting Queen Street High-Level Station. The dynamo leads are not connected directly with the centre rail, but to three Hedges' patent safety fuses in the engine-room, in case of a short circuit. (Fig. 1.)

The tunnel is divided into three circuits—namely, College to Queen Street Station (Low Level), and Queen Street to Charing Cross and to Finnieston. By this means, in the event of there being a breakdown in either tunnel, it can be switched off so as not to interfere with the other two. The length of each circuit is 748, 484, and 2,196 lineal yards, respectively.

The area of the centre rail increases as it leaves the dynamo, while the resistance of each circuit is the same.

The estimated loss or fall in potential at the end of each circuit with a train in it was 10 volts, and it is found that at Finnieston Station, which is 2,196 yards away, such is the case.

It is possible to have two trains in two of the circuits, and four in the other, or eight in all; and the cables leading to each have been arranged accordingly. Insulated cables laid in creosoted troughing and filled with pitch have been laid from the dynamo to the centre and ordinary rails.

The wires from the contact pulleys are connected to two 16 candle-power lamps, which have been placed in each compartment, fixed on either side of the ordinary roof lamp, so as not to interfere with it, and in order that the latter may be used when required. (Fig. 2.) These lamps, which are of the Swan type, are 25, 50, and 100 volt lamps. Only one is lit at a time, the second being a reserve, which automatically lights itself in the event of the first one failing. This is accomplished by means of a small "cut-out" or electro-magnet, round which the current flows to the first lamp. The other lamp is connected to a spring, but it is only put into circuit by the armature of the electro-magnet being released. Each of these "cut-outs" carries a small fusible wire which prevents the lamp being burned up in the event of too much current passing. (Fig. 5.)

Each circuit is formed in the following way:—The positive lead to the lamps is connected to the two contact pulleys, while the negative is connected to the spring of the carriage. It will thus be seen that as soon as the train enters the tunnel the pulleys *make* contact with the centre rail, the current flowing from the

dynamo through the centre rail and pulleys to the lamps, and returning through the spring and wheels of the carriage to the ordinary rail, and through it back to the dynamo again. On the train leaving the tunnel the pulleys run down the inclined plane of the centre rail, breaking the connection and so putting the lamps out. As regards the power required for each train, it may be said to be about 2,000 Watts, or from two to three horse-power.

In case of a short circuit occurring between the centre and ordinary rails, by a locomotive or other vehicle, a small indicator has been placed on each line of rails, and is connected by an electric bell with the engine-house. It is placed a little higher than the centre rail, so as to call attention before "short-circuiting" with the latter takes place.

In order to prevent the rusting of the centre rail, or to keep it clean so as to make good contact, a steel wire brush is being fixed on one carriage in each train. It is found that the brush makes better contact and gives a steadier light than the pulley, but, owing to the friction, the tear and wear would be too great to adopt it entirely.

As to the effect of coming in contact with the centre rail, there is no danger: the potential is too low, and although some men do feel the current a little, others again cannot feel anything. The advantage of using a high potential is that smaller wires or a lighter area of centre rail can be used, while the fall or loss in working is not so great. The potential used here is only half of that allowed by the Board of Trade—namely, 200 volts.

It is found that the small "cut-outs" work best either with the 25 or 50 volt lamps, as they take more current, but when regulated and connected to a single 100 volt lamp they act well.

As already mentioned, the end of the centre rail at Finnieston Station, which is furthest away from the dynamo, is distant about $1\frac{1}{4}$ miles (2,196 lineal yards); and at this point, with one train in circuit, having 36 lamps, the potential is 100 volts, or that required to light the lamps.

The insulation of the centre rail is not quite perfect, there being a slight leakage, but it cannot be traced to any particular part, and it is practically inappreciable. This may arise by the steam conveying the current to "earth," as on a dull day the centre rail is quite wet; and in the distance from the dynamo to Finnieston the area exposed is no less than 840 square yards on one line alone, so that the leakage is not to be wondered at.

It will be seen that by this system the train, or rather each carriage, is lighted and extinguished on entering or leaving the tunnel—automatically, as it were. There are no connections between the carriages, so that the train can be broken up or shunted as usual, while the light is maintained whether the train is in motion or at a stand.

During the New Year holidays some of the trains were running with only one carriage fitted, while others had six or eight fitted and the remainder not.

During the passage of these trains through the tunnel the speed of the dynamo was nearly constant, and their presence in the circuit could only be detected by a slight hissing noise at the commutator brushes, and faint sparking, if any.

This system has now been in use four months, and two trains have been running all this time, only being off one day weekly to be cleaned.

The number of lamps in the two trains was on an average 60; and, in the four months' lighting, three of them have had to be renewed. Two of the three were broken maliciously, the outside globes having been broken also, while in the other the carbon filament gave way, having burned 100 hours.

[Since this paper was read, eight trains—or, in all, 74 carriages—have been fitted, and are running daily. Taking the running of these trains for six months, the total number of lamp hours is 39,642. During this time it has been necessary to replace 44 lamps, so that the average life of the lamps has been 900 hours each; but as 11 of these lamps were broken maliciously by passengers in the trains, their actual life is 1,210 hours.]

In this system the electric light is not used at night, the gas or oil lamps being still made use of, which are there to fall back on should a breakdown take place.

In the other systems the electric light was used alone, and could be made use of at any time, whereas in this it can only be had in the tunnels. Of course, it has the advantage of allowing the trains to be broken up (which is done sometimes twice a day), without having any extra couplings, and having the light only when required, without the control of anyone.

The cost of this system is less by a fourth than that of either of the other two, and fully a third less than that of gas, while the working expenses are much the same as the first two systems, but *a third* less than gas-lighting.

Fig. 1.

Fig. 2

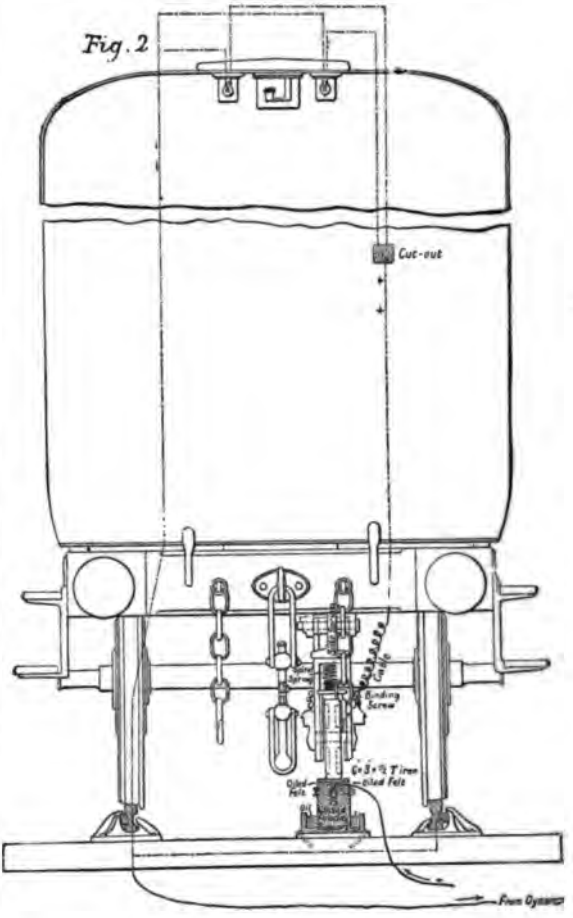


Fig. 3.

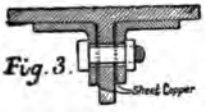
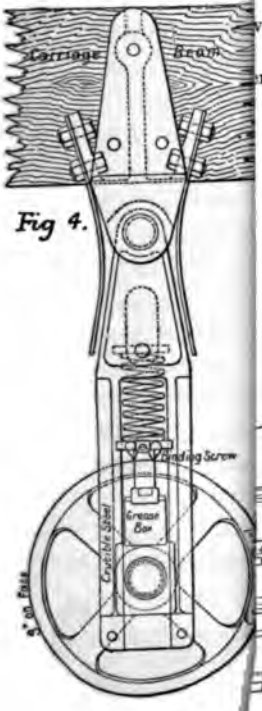


Fig 4.



REPORTS OF SECTIONS.

FOR SESSION 1886-87.

[Received at Meeting of Society on 4th May, 1887.]

1.—Report of the Architectural Section.

During the Session eight Meetings have been held, at which twelve papers have been read. The following is a list of the papers read at the Meetings:—

Monday, *November 16, 1886.*—Opening Meeting, when James Thomson, Esq., Architect, F.R.I.B.A., President of Section, gave his address.

Monday, *November 29, 1886.*—A. Buchanan Miller, Esq., read a paper on "Some Notes on the proper Ventilation of Public Buildings by Mechanical Means."

Monday, *December 13, 1886.*—John Honeyman, Esq., Architect, F.R.I.B.A., read a paper on "Incidence of Taxation as affecting the Housing of the Poor."

Monday, *January 17, 1887.*—E. C. Morgan, Esq., read a paper on "Cements and their Uses;" and J. W. Mackie, Esq., Marble Cutter, read a paper on "Marbles and Tiles."

Monday, *January 31, 1887.*—Andrew Robson, Esq., Architect, read a paper on "The Nature and Capabilities of Timber adapted for Building Purposes;" and W. G. Lindsay, Esq., C.A., read a paper on "North Carolina and its Timber Forests."

Monday, *February 14, 1887.*—Archibald Ferguson, Esq., Writer, read a paper on "Some Minor Rights of Land Ownership;" and A. Lindsay Miller, Esq., Architect, read a "Short Sketch of the History of the Society."

Monday, *February 18, 1887.*—Duncan Dewar, Esq., read a paper on "Decorative Art;" and Joseph Potts, Esq., C.E., read a paper on "Urban and Suburban Drainage."

Monday, *March 14, 1887.*—James P. M'Gilvray, Esq., Sculptor, read a paper on "Technical Education."

The thanks of the Section are due to all those gentlemen. During the Sesson 15 Associates joined the Section.

The Annual Business Meeting was held on Monday, March 15, when the following gentlemen were elected to office:—

President—James Thomson, Esq., Architect.

Vice-Presidents—Thomas Gildard, Esq., Alexander Muir, Esq., Builder.

Treasurer—Mr. James Howatt, Measurer.

Secretary—Mr. A. Lindsay Miller, Architect, 121 West Regent Street.

Members of Council—James Sellars, Esq., Architect; David Thomson, Esq., Architect; James Chalmers, Esq., Architect; T. L. Watson, Esq., Architect; David Barclay, Esq., Architect; R. A. M'Gilvray, Esq., Plasterer; William Gilfillan, Esq., Marble Cutter; William Howatt, Esq., Measurer; William Cairns, Esq., Plumber; James Parnie, Esq., House Factor.

(Signed) A. Lindsay Miller, *Architect*,
Hon. Secretary of Section,
121 West Regent Street.

2.—Report of the Geographical and Ethnological Section.

During the Session three papers from the Section were read before the Society. 1st, "On the Manners and Customs of some of the Tribes of New Guinea," by the Rev. James Chalmers, on 10th November; 2nd, "Geographical Alto-Relievo Models and their place in Education," by Mr. Wm. Martin, on 2nd February; 3rd, on "The Australian Aborigine, as he was," by Mr. Arthur Kay, also on 2nd February. In addition to these, two Meetings were held under the arrangement for holding Joint Meetings with the West of Scotland Branch of the Scottish Geographical Society, at which the following papers were read:—1st, "The Congo: its Past and Present," by Colonel Sir Francis de Winton, on 26th January; 2nd, "Japan," by Consul Russell Robertson, on 19th April.

Office-Bearers for 1886-87.

President—W. G. Blackie, Ph.D., LL.D., F.R.G.S.

Vice-Presidents—James Stevenson, F.R.G.S.; Sir Michael Connal; Thomas Muir, M.A., LL.D., F.R.S.E.

Secretary and Treasurer—G. A. Turner, M.D., C.M.

Members of Council—Jas. Christie, A.M., M.D.; Mr. William Ewing, Mr. Nathaniel Dunlop, Mr. Robt. Gow, Mr. Jas. Grierson,

Mr. Maxwell Hannay, Mr. William Ker, Mr. Jacques van Raalte, Mr. Alexander Scott, Mr. W. Renny Watson, Mr. Arthur Kay, Mr. Robert Blyth, C.A.

(Signed) GEO. A. TURNER, M.D.,
Secretary.

3.—REPORT OF THE BIOLOGICAL SECTION.

The Section held no Meetings of its own during the Session, but a number of communications were brought forward at General Meetings of the Society.

Mr. Wm. Milne read a paper "On a New Tentaculiferous Protozoon and other Infusoria, with Notes on Reproduction and the Function of the Contractile Vesicle."

Mr. A. B. Kelly gave a demonstration of a new method of preparing and cutting Microscopical Sections.

Professor F. O. Bower read two papers: (1) "On the Relations of Black Ants to the Plant *Humboldtia laurifolia*;" (2) "On a Morphological Peculiarity in *Cordyline Australis*."

Dr. John Yule Mackay read a paper on "The Comparative Anatomy of the Vertebral Artery."

(Signed) JOHN YULE MACKAY, M.D.,
Secretary.

4.—REPORT OF THE MATHEMATICAL AND PHYSICAL SECTION.

A Meeting of the Section was held on the 17th November, 1886, at which the following Office-Bearers were elected:—

President—Sir William Thomson, LL.D., D.C.L., &c.

Vice-Presidents—Thomas Muir, M.A., LL.D., and Professor Robert Grant, M.A., LL.D., F.R.S.

Secretary and Treasurer—Robert Franklin Muirhead, M.A., B.Sc.

Members of Council—Peter Alexander, M.A.; Professor James Blyth, M.A.; James Thomson Bottomley, M.A.; Henry Dyer, M.A., C.E.; Professor William Jack, LL.D.; Principal Andrew Jamieson, F.R.S.E.; Professor James Thomson, LL.D., F.R.S.; William Renny Watson, James Wood, M.A.

Two Sectional Meetings were held during the Session; one on the 30th of November, 1886, and one on the 3rd of February, 1887. At the former a paper by Mr. Peter Alexander on

MINUTES OF SESSION.

3rd November, 1886.

The Philosophical Society of Glasgow held its First Meeting for Session 1886-87 on the evening of 3rd November, 1886, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society were read,* and were approved of, and signed by the Chairman.

2. The following were proposed for the Membership of the Society:—

Mr. J. H. Fullarton, M.A., B.Sc., Natural History Department, University. Recommended by Dr. M'Kendrick, Dr. M'Gregor Robertson, and Mr. J. T. Bottomley.

Mr. Alexander Leitch, Secretary and Manager, 60 Rosebank Terrace. Recommended by Dr. Andrew Fergus, Dr. M'Kendrick, and Dr. M'Gregor Robertson.

Mr. Charles S. Moir, Calico Printer, 92 Union Street. Recommended by Mr. R. M. Downie, Dr. A. Wallace, and Dr. M'Kendrick.

Mr. John Watson, Merchant, 205 West George Street. Recommended by Mr. Daniel Munro, Mr. John Mann, and Dr. M'Kendrick.

Mr. Charles W. Cayzer, Steamship Owner, 109 Hope Street. Recommended by Mr. Maxwell Hannay, Mr. John Mann, and Dr. M'Kendrick.

3. Mr. C. M. Aikman, M.A., B.Sc., F.C.S., was admitted to the Membership of the Society.

4. Mr. Henry Dyer, M.A., B.Sc., C.E., read a paper on "The Development of the Marine Engine," for which he received a cordial vote of thanks.

---

* 12th May, 1886. See Vol. XVII., p. 437.

5. On the motion of Dr. M'Kendrick, Mr. Robert Gow and Mr. George S. Buchanan were appointed Auditors of the Treasurer's Accounts for the past year.

6. Dr. Turner, on behalf of the Scottish Geographical Society, presented several books to the Society, for which the S. G. Society and Dr. Turner were awarded a vote of thanks.

7. The President announced that the following gentlemen had been duly elected Members of the Society:—

Mr. Walter Wilfrid Blackie, 1 Belhaven Terrace. Recommended by Dr. W. G. Blackie, Dr. M'Kendrick, and Dr. M'Gregor Robertson.

Mr. William Buchanan, Registrar, 10 Carrington Street. Recommended by Mr. A. Scott, Dr. James B. Russell, and Mr. R. F. Muirhead.

Mr. Ventura de Callajon, Spanish Consul, 2 Carlton Terrace, Kelvinside. Recommended by Mr. Jacques van Raalte, Dr. M'Kendrick, and Dr. M'Gregor Robertson.

Mr. Stephen Cooke, 85 Buccleuch Street. Recommended by Principal M'Call, F.R.C.V.S., Mr. John Tatlock, and Dr. William Limont.

Mr. Robert Crawford, Merchant, 84 Miller Street. Recommended by Dr. M'Kendrick, Mr. David Sandeman, and Dr. M'Gregor Robertson.

Mr. C. D. Gairdner, C.A., 115 St. Vincent Street. Recommended by Mr. Charles Ker, Dr. M'Kendrick, and Dr. M'Gregor Robertson.

Mr. James Murray MacKinlay, 4 Westbourne Gardens. Recommended by Mr. David MacKinlay, Mr. Henry Dyer, and Dr. M'Kendrick.

Mr. William Smart, M.A., Lecturer on Political Economy, &c., Nunholm, Dowanhill. Recommended by Mr. Henry Dyer, M.A., Mr. David MacKinlay, and Dr. M'Kendrick.

Mr. James Thomson, Architect, F.R.I.B.A., 88 Bath Street. Recommended by Mr. A. Lindsay Miller, Mr. T. L. Watson, and Mr. John Mann.

(Signed) HENRY MUIRHEAD.

(Minutes of Session continued on page 409.)

Dr. **ABSTRACT OF TREASURER'S**

1885.—Nov. 1.								
To Balance in Treasurer's hands at end of last Session, . .							£4	6 2
1886.—Oct. 31.								
To Entry-money from 47 New Members, at 21s.,				£49	7	0		
,, Annual Dues from 2 Members for 1884-85, at 21s., . .	£2	2	0					
,, Annual Dues from 535 Ordinary Members for 1885-86, at 21s.,	561	15	0					
,, Annual Dues from 44 New Members for 1885-86, at 21s.,	46	4	0					
				610	1	0		
,, Life Subscription from 3 New Members, at £10 10s., .	£31	10	0					
,, Life Subscription from 3 Old Members, at £10 10s., .	31	10	0					
				63	0	0		
							£722	8 0
,, Corporation of Glasgow, Interest on "Exhibition Fund" for year to Whitsunday, 1886—less Income Tax, .							19	13 2
,, Bank Interest, ...							3	4 2
,, *Proceedings* and *Catalogues* sold, ...							1	13 6
,, ARCHITECTURAL SECTION—								
79 Associates' fees, at 5s., ...							19	15 0
,, GEOGRAPHICAL AND ETHNOLOGICAL SECTION—								
5 Associates' fees for 1884-85, at 5s., .				£1	5	0		
35 Do., for 1885-86, at 5s., .				8	15	0		
							10	0 0
,, MATHEMATICAL AND PHYSICAL SECTION—								
10 Associates' fees for 1885-86, at 5s., . . .							2	10 0
							£783	10 0

Memo. by Treasurer.—The Amount invested by the Society in the Bath Street Joint Buildings up to 31st October, 1886, is . £3,547 8 1½

whereof, Paid from Society's Funds,	£1,847	8	1½		
Do. Private Loan, .	200	0	0		
Do. Society's half of £3,000 Bond, .	1,500	0	0		
				£3,547	8 1½

J. M.

ACCOUNT—SESSION 1885-86. Cr.

1886.—Oct. 31.

By Salary to Secretary,			£75	0	0	
,, Allowance for Treasurer's Clerks,			15	0	0	
,, Demonstrations at Lectures,			1	16	10	
						£91 16 10
,, New Books, Periodicals, and Foreign Periodicals,			£130	0	2½	
,, Bookbinding,			32	13	9	
,, Printing Circulars, *Proceedings*, &c.,			222	10	0	
,, Lithographs and Woodcuts for *Proceedings*, &c.,			41	11	6	
,, Postage and delivery of Circulars, Letters, and Parcels,			42	1	8	
,, Stationery, Diplomas, &c.,			8	5	0	
,, Illuminated Address to M. Chevreul,			8	12	6	
			£485	14	7½	
Less—Contribution to Cost of Illustrations in Vol. XVII. of *Proceedings*,			2	1	0	
						483 13 7½
,, Fire Insurance on Library for £5,400,			£5	18	0	
,, Postages, &c.—per Treasurer, £2 13s. 9d.; per Secretary, £6,			8	13	9	
,, Frames, Repairs, &c.,			3	18	6	
,, Interest on Loan of £200,			7	4	6	
						25 14 9
,, SUBSCRIPTIONS TO SOCIETIES—						
Ray Society, 1886,			£1	1	0	
Palæontographical Society, 1886			1	1	0	
						2 2 0
,, ARCHITECTURAL SECTION—						
Expenses per Treasurer of Section,						16 8 6
,, MATHEMATICAL AND PHYSICAL SECTION—						
Expenses per Treasurer of Section,						1 0 0
,, GEOGRAPHICAL AND ETHNOLOGICAL SECTION—						
Expenses per Treasurer of Section,						4 7 3
,, SANITARY AND SOCIAL ECONOMY SECTION—						
Expenses per Treasurer of Section,						0 3 6
JOINT EXPENSES OF ROOMS—						
Society's half of £337 17s. 7d., being Interest on Bond, Insurance, Taxes, Cleaning, Lighting, and Heating; Salaries of Sub-Librarian and Assistant—less half of £63 15s. Revenue from Letting,						137 1 3½
,, Balance in Treasurer's hands,						21 2 3
						£783 10 0

GLASGOW, *10th November, 1886.*—We, the Auditors appointed by the Society to examine the Treasurer's Accounts for the year 1885-86, have examined the same, of which the above is an Abstract, and have found them correct, the Balance due by the Treasurer at 31st October last being Twenty-one Pounds Two Shillings and Threepence.

(Signed) ROBERT GOW.
GEO. S. BUCHANAN.

GRAHAM MEDAL AND LECTURE FUND.

ABSTRACT OF TREASURER'S ACCOUNT.—SESSION 1885-86.

Dr. **Cr.**

CAPITAL AT 1ST NOVEMBER, 1885—						CAPITAL AT 31ST OCT., 1886—				
Glasgow and South-Western Railway Co. 4 % Preference Stock in name of the Philosophical Society, in Trust,	£250	0	0			Investment,	£250	0	0	
Value of Die at H. M. Mint,	18	18	0			Die,	18	18	0	
				£268	18	0				268	18	0
Cash in Union Bank,	£9	10	7			Cash in Union Bank,	£19	7	8			
Cash in Treasurer's hands,	0	11	8			Cash in Treasurer's hands,	0	11	8			
				10	2	3				19	19	4
REVENUE—												
Dividend, April 22, 1886, less Tax,	£4	16	8									
,, Oct. 1, ,, ,,	4	16	8									
Interest from Bank,	0	3	9									
				9	17	1						
				£288	17	4				£288	17	4

WM. WALLACE, *Treasurer.*

10th November, 1886.

The Philosophical Society of Glasgow held an Extra Meeting in conjunction with the Scottish Geographical Society, in the Rooms of the Society, 207 Bath Street, on the evening of Wednesday, the 10th of November, 1886—Dr. W. G. Blackie, President of the Geographical and Ethnological Section, in the Chair.

The Rev. James Chalmers of New Guinea read a paper on "The Manners and Customs of some of the Tribes of New Guinea," for which he received a cordial vote of thanks, on the motion of Sir Michael Connal.

Report on the State of the Society by the Council for Session 1885-86.

I. *Meetings.*—The Society held 14 Meetings during the Session, which was opened on 4th November, 1885, and closed on 12th May, 1886. At these Meetings 42 papers were read, 30 of which appear in the *Proceedings.* Two Joint Meetings with the Scottish Geographical Society were also held, at which 3 papers were read, one of which appears in the *Proceedings.*

II. *Membership.*—The number of Members on the Roll at the beginning of Session 1885-86 was 669; during the Session 47 new Members were elected, making 716; of these 31 have resigned, 14 have died, 1 has left Glasgow and his name has been placed on the Suspense List, and 8 have been struck off the Roll for non-payment of annual subscription; leaving on the Roll at the beginning of the present Session 662 Members, being a decrease of 7. Of the 47 new Members, 3 became Life Members; and 3 Ordinary Members also paid the composition of Life Members during the Session. Two vacancies exist in the list of Honorary Members. There are at present 18 Honorary Members, of whom 6 are Continental, 5 are American or Colonial, and 7 are British. The number of Corresponding Members is 11. The Membership of the Society then is as follows:—Honorary Members, 18; Corresponding Members, 11; Ordinary Members, 662; or a total of 691.

III. *Sections.*—(1) During the Session the *Architectural Section* held eight Meetings, at which 11 papers were read, and one of these, the President's address, appears in the *Proceedings.*

(2) The Council much regret that the *Chemical Section* has practically been in abeyance during the past session, and they earnestly hope that something may be done to induce the Chemists of Glasgow, as in former years, to send some of their contributions to the Philosophical Society.

(3) *The Sanitary and Social Economy Section.*—This Section contributed 2 papers to the General Meetings of the Society, both of which appear in the *Proceedings.*

(4) *The Geographical and Ethnological Section.*—During the Session this Section contributed 5 papers to the General Meetings of the Society, 4 of which appear in the *Proceedings.* In addition, 2 papers were read which were contributed to the Scottish Geographical Society. The joint-arrangement between this Society and the Scottish Geographical Society, with the consent of the Council of the Institution of Engineers and Shipbuilders, has worked admirably, and has been the means of encouraging the cultivation of Geographical Science in Glasgow.

(5) *The Biological Section.*—This Section, although it held no separate meetings, sent to the General Meetings of the Society 11 contributions, 8 of which appear in the *Proceedings.*

(6) *The Mathematical and Physical Section.*—This Section made 6 contributions to the General Meetings, 1 of which appears in the *Proceedings.* No sectional meetings were held.

Thus, with the exception of the Chemical Section, all the sections have been in active operation, and have done good service in sending papers to the General Meetings of the Society. No doubt, if a sufficient number of papers were offered, it would be highly desirable to have sectional meetings, but even if these are not held, the sections aid the society by fostering the science under their special care.

IV. *Proceedings.*—The volume of *Proceedings* of the Society for 1885-86, Vol. XVII., contains 31 Papers, is illustrated by 11 Plates, 1 coloured Map, 1 coloured Diagram, and a Photograph, and it contains valuable contributions to science. There can be no doubt that the publication of such papers, although they may be of a technical nature, will enhance the reputation of the Society among men of science in all countries, as it will show that the Society does not exist merely for the diffusion of general knowledge among its members, but for the higher function of fostering science even of the most abstruse and technical character. The more original the quality of the papers in the *Proceedings* the greater will be the value of the volume, as a medium of exchange with other societies, and thus year by year a great collection of the *Proceedings* and *Transactions* of the scientific societies of the world will be built up in Glasgow.

V. *Finance.*—The Treasurer's Statement shows that the Floating Debt of the Society remains practically the same as last year. That no reduction was made is to be attributed, on the one hand, to Life Membership subscriptions having yielded £42 less than last year, while, on the other hand, the cost of *Proceedings*, New Books, &c., is £80 over that of last year.

By order and on behalf of the Council.

(Signed) JOHN G. M'KENDRICK,
Secretary.

17th November, 1886.

The Philosophical Society of Glasgow held its Eighty-fifth Annual Meeting on the evening of the 17th November, 1886, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the Notice calling the Meeting, were held as read, were approved of, and were signed by the Chairman.

2. Mr. Walter Wilfrid Blackie, Mr. William Buchanan, Mr. Ventura de Callajon, Mr. Stephen Cooke, Mr. Robert Crawford, Mr. C. D. Gairdner, C.A., Mr. James Murray MacKinlay, Mr. William Smart, M.A., and Mr. James Thomson, F.R.I.B.A., were admitted to the Membership of the Society.

3. The following were proposed for the Membership of the Society:—

Mr. Peter Fyfe, Sanitary Inspector, 1 Montrose Street. Recommended by Mr. John Young, Mr. John Mann, and Mr. A. Lindsay Miller.

Mr. James Erskine, M.A., M.B., 6 Newton Street, Charing Cross. Recommended by Dr. Glaister, Mr. Alexander Scott, and Dr. M'Kendrick.

4. The Annual Report by the Council on the state of the Society, having been printed in the billet calling the Meeting, was held as read, and was unanimously adopted, and ordered to be printed in the *Proceedings*.

5. The audited Statement of Accounts for Session 1885-86, by Mr. John Mann, Treasurer, having been printed in the billet calling the Meeting, was held as read, was approved of, and was ordered to be printed in the *Proceedings* for future reference. The Treasurer also submitted an Inventory of the Furniture, &c., of the Society, which was ordered to be printed in the *Proceedings* for future reference.

6. Mr. John Robertson, Librarian, and Convener of the Library Committee, read the Annual Report on the Library

which was adopted, and ordered to be printed in the *Proceedings*. The Report was as follows:—

REPORT OF THE LIBRARY COMMITTEE.

During the past year there has been a considerable increase in the number of volumes added to the Library, but the number of readers has not been so great.

There were issued 816 volumes to 573 members. At present 94 different periodicals lie on the tables. Of these 55 are bought, and 39 are received in exchange. They form altogether 141 volumes a-year.

The presentations to the Society during the year included 47 volumes, 4 parts, and 45 pamphlets; and 73 volumes and 148 parts have been received in exchange from 143 Societies and Public Departments. Sixty-five volumes have been bought.

The total additions to the Library for the year amount to 326 volumes, 152 parts, and 45 pamphlets.

Correspondence has been opened up with La Société Malacologique de Belgique, the Editor of "Industries," the Liverpool Naturalists' Field Club, the French Canadian Institute, the Geographical Society of Griefswald, Prussia; the National Astronomical Observatory of Mexico, and Nederlandsch Aardrijkundig Genootschap.

In Volume XVII. of the *Proceedings* will be found a list of the additions to the Library by purchase during last session, the titles of the volumes presented, with the names of the donors, the names of the Societies and Public Departments with which exchanges are effected, and a complete list of the periodicals received by the Society.

During the year 219 volumes were bound.

The estimated number of volumes in the Library is 9,837. The book-cases are completely filled, and consideration is being given to the means of finding increased accommodation.

(Signed) JOHN ROBERTSON,
Convener.

Mr. Robertson also submitted the following list of Presentations to the Library:—

Annual Report of Chief Signal Officer to Secretary of War, 2 parts; U.S. Geological Survey, 4th Report and 5th Report; Brachiopoda and Lamellibranchiata of the Clays and Greensand Marls of New Jersey. From the American Government.

Proceedings and Transactions, Vol. 2. From the Royal Society of Canada.

Pouillet's Elements of Physics, 2 vols.; Serret's Differential and Integral Calculus, 2 vols.; Boucharlat's Elements of Mechanics. From Dr. Thomas Reid.

Statistics of Glasgow, 1881-5. From the City Chamberlain.

Several Volumes and Pamphlets bearing on Canada; also a large Map of Canada. From Mr. Thomas Graham, Agent of the Canadian Government, for Scotland.

A Reprint of "Hocus Pocus," an old Glasgow Book. From Mr. John Anderson.

Clinical Manual for the study of Medical Classes. From Dr. Finlayson.

Report of the American Association for the Advancement of Science, Philadelphia Meeting; Handbook of Birmingham, issued by Local Committee of British Association Meeting, 1886; Vestiges of the Natural History of Creation, 9th edition, 1851. From Dr. Muirhead.

Observations of the International Polar Expedition. From the Meteorological Office.

7. A vote of thanks was unanimously passed to the Librarian and Treasurer for their services during the past year.

8. The Society then proceeded to the election of Office-bearers.

(1.) On the Recommendation of the Council, Dr. HENRY MUIRHEAD nominated, as his successor in the Presidential Chair, JAMES B. RUSSELL, B.A., M.D., LL.D., Medical Officer of Health for the City of Glasgow, for the term of three years. The motion was carried by acclamation. On taking the Chair, the new President thanked the Society for the honour conferred upon him; and, on the motion of Dr. JAMES MORTON, a very cordial vote of thanks was awarded to the retiring President, who becomes an Honorary Vice-President.

(2.) Mr. J. J. COLEMAN, F.C.S., F.I.C., F.R.S.E., recommended by the Council, and on the motion of Mr. ALEXANDER SCOTT, was elected a Vice-President in room of that gentleman, whose term of office had expired.

(3.) Messrs. JOHN ROBERTSON and JOHN MANN were re-elected to their respective offices of Librarian and Treasurer.

(4.) The PRESIDENT, on behalf of the Council, nominated Mr. JAMES PATON, F.L.S., as the Secretary, in succession to Dr. M'Kendrick, who wished to retire. Mr. MUNSIE seconded the nomination. Mr. DAVID ROWAN proposed Mr. JOHN MAYER for the vacant office, and the motion was seconded by Mr. JOHN TURNBULL, jun. The members then balloted for the two Candidates—Messrs.

Dyer and Munsie (for Mr. Paton), and Messrs. Rowan and Turnbull (for Mr. Mayer), being appointed scrutineers. Subsequently, Mr. Rowan reported on behalf of the scrutineers that the votes were—Mr. Paton, 76; Mr. Mayer, 78; with four blank papers. On the result of the voting being announced, Dr. M'Gregor Robertson asked that the President should put Mr. Mayer's appointment as a substantive motion to the meeting, as he was prepared with an amendment. This proposal gave rise to a discussion, in which the speakers were Mr. Scott, Mr. Paton, Dr. M'Kendrick, Mr. Robert Crawford, Mr. James Thomson, and Mr. William Fife. The President interposed by announcing that the vote had been taken in accordance with the rules and the practice of the Society, that it was in favour of Mr. Mayer, and that it was final. Mr. Mayer at once entered upon the duties of the office, and on the motion of Sir William Thomson, a most enthusiastic vote of thanks was passed to Dr. M'Kendrick for the able manner in which he had discharged the duties of the Secretaryship during the past six years.

(5.) While the scrutiny of the votes was proceeding, the Society filled four vacancies in the Council, caused by the retiral by rotation of Sir Michael Connal, Mr. Archibald Robertson, Professor Blyth, and Principal Jamieson. The new Members elected were Professor M'KENDRICK, M.D., Mr. HENRY DYER, M.A., C.E., Mr. WILLIAM MILNE, M.A., B.Sc., and Dr. GEORGE A. TURNER.

(6.) Various Office-bearers of the Geographical and Ethnological Section were appointed according to Resolution of Society of 11th April, 1883, and of the Chemical, Biological, Sanitary and Social Economy, and Mathematical and Physical Sections, in accordance with Resolution of Society of 18th November, 1885.

9. On the motion of Dr. M'Kendrick, it was resolved to appoint Mr. Archibald Robertson to serve as a Member of the House Committee.

10. Mr. Adolf Schulze afterwards read a paper on "Dr. E. Abbe's New Apochromatic Lenses and Compensating Eye-pieces," which are made in the optical works of Dr. Carl Zeiss, of Jena. At the close of the paper a question was asked of Mr. Schulze by Mr. P. Falconer, and some remarks were made on the subject of the paper by Dr. M'Kendrick and Dr. Joseph Coats; and on the motion of the President a vote of thanks was awarded to the author of the paper.

11. Dr. M'Kendrick exhibited, and briefly described, a new Rocking Microtome (for cutting microscopical sections in a continuous ribbon), and other specimens of new physiological

apparatus. He received the thanks of the Society for his interesting communication.

12. The following gentlemen were declared to be duly elected into the Society:—Mr. J. H. Fullarton, M.A., B.Sc., Natural History Department, University; Mr. Alexander Leitch, Secretary and Manager, 60 Rosebank Terrace; Mr. Charles S. Moir, Calico Printer, 92 Union Street; Mr. John Watson, Merchant, 205 West George Street; Mr. Charles W. Cayzer, Steamship Owner, 109 Hope Street.

(Signed) HENRY MUIRHEAD.

1st December, 1886.

The Philosophical Society of Glasgow held its Second Ordinary General Meeting for Session 1886-87 on the evening of the 1st December, 1886, at eight o'clock, in the Rooms of the Society, 207 Bath Street—Dr. James B. Russell, President, in the Chair.

1. The Minutes of the preceding Meeting of the Society, which were printed in the Notice calling the Meeting, were held as read, with the exception of paragraph 4 under the head of "Election of Office-Bearers." The amended entries in the Minute-Book having been read by the Secretary, the whole were approved of by the Meeting, and signed by the Chairman.

2. The following were admitted to the Membership of the Society:—Mr. J. H. Fullarton, M.A., B.Sc.; Mr. Alexander Leitch; Mr. Charles S. Moir; Mr. John Watson; and Mr. Charles W. Cayzer.

3. The following were proposed for election into the Society:—

Mr. William Stevenson Brown, Iron Tube Manufacturer, 41 Oswald Street. Recommended by Mr. William Foulis, Mr. Thomas Menzies, and Mr. John Mayer.

Mr. Francis H. Underwood, U.S. Consul, 107 West Regent Street. Recommended by Dr. James B. Russell, Dr. Henry Muirhead, and Mr. John Mayer.

Mr. Thomas Machell, Pianoforte and Music Seller, 39 Great Western Road. Recommended by Dr. James B. Russell, Dr. James Christie, and Mr. John Mayer.

Mr. Thomas Downie, Hydepark Foundry, Finnieston Street. Recommended by Mr. Alexander Wilson, Mr. Henry Dyer, and Mr. John Mayer.

Mr. Alexander George Moore, M.A., B.Sc., Civil and Mining Engineer, 13 Clairmont Gardens. Recommended by Mr. James M'Creath, Dr. J. B. Russell, and Mr. John Mayer.

4. On behalf of Mr. William Smart, M.A., who was unavoidably absent, Mr. Dyer gave notice of motion to the following effect:—"That steps be taken to form an Economical Section."

5. The President announced that the Council had favourably considered a suggestion to have a General Index to the *Proceedings* compiled, and hoped that one or more members of the Society having the requisite leisure might volunteer their services. He also made the following announcement on behalf of the President and Council of the Chemical Section:—"The Graham Medal for the best Original Investigation in Chemical Physics or Pure or Applied Chemistry will be awarded for the best Paper read to the Society during the three Sessions ending April, 1887. Papers should be communicated as early as possible in the Session to the Secretary."

6. Mr. William Key, Manager, Corporation Gas-works, Tradeston, read a paper on "The Coal Question and its Bearing on the Illuminating Power of Gas." A discussion followed, in which Dr. William Wallace, Mr. J. J. Coleman, and Councillor Crawford took part. Mr. Key was awarded a vote of thanks for his paper.

7. The following gentlemen were declared to be duly elected Members of the Society:—Dr. James Erskine, M.A., 6 Newton Place; Mr. Peter Fyfe, Sanitary Inspector, 1 Montrose Street; Mr. R. W. Emerson MacIvor, F.I.C., F.C.S., 67 Great Clyde Street; Mr. John Lochore, Head Master, Fairfield Public School, Govan; Mr. Robert Bryce, Plumber, 82 Oswald Street; Mr. T. A. Craig, C.A., 139 St. Vincent Street; Mr. Azariah Griffiths, Coalmaster and Firebrick Manufacturer, Falkirk; Mr. James Wood, Coalmaster, 40 St. Enoch Square.

8. Before the Meeting separated, Mr. Mayer thanked the Society for having at the Annual Meeting elected him to the highly honourable office of Secretary to the Society, in succession

to Dr. M'Kendrick—a duty which he had not previously had the opportunity of discharging.

(Signed) HENRY MUIRHEAD.

15th December, 1886.

The Philosophical Society of Glasgow held its Third Ordinary General Meeting for Session 1886-87 on the evening of the 15th December, 1886, at eight o'clock, in the Rooms of the Society, 207 Bath Street—Dr. James B. Russell, President, in the Chair.

1. The Minutes of the preceding Meeting of the Society, which were printed in the Notice calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following were admitted to the membership of the Society:—Dr. James Erskine, M.A., Mr. Peter Fyfe, Mr. R. W. Emerson MacIvor, Mr. John Lochore, Mr. Robert Bryce, Mr. T. A. Craig, Mr. Azariah Griffiths, and Mr. James Wood.

3. The following Candidates were proposed for election into the Society:—

Mr. Walter MacLean, Lithographer, 2 Bothwell Circus. Recommended by Mr. John Mann, Dr. James Morton, and Dr. John G. M'Kendrick.

Mr. James Russell Motion, Acting Inspector of Poor, Barony Parish. Recommended by Messrs. Jas. Parnie, John Mayer, and John Mann.

4. Dr. Henry Muirhead read his "Report from the Conference of Delegates of Corresponding Societies in connection with the British Association. Birmingham Meeting, September, 1886." On the motion of the President, the report was received, and Dr. Muirhead was awarded the thanks of the Society.

5. On behalf of Mr. David Sandeman, who was unable to attend, Dr. J. M'Gregor Robertson read a paper on "Recent Progress in Technical Education, with special reference to the Glasgow Weaving School." Several members spoke on the subject of the paper, and the thanks of the Society were awarded to the author.

6. Mr. William Milne, M.A., B.Sc., submitted a Paper, entitled, "On a New Tentaculiferous Protozoon and other Infusoria, with Notes on Reproduction and the Function of the Contractile Vesicle." A short discussion took place upon it, and Mr. Milne received the thanks of the Society for his paper.

7. Mr. R. F. MUIRHEAD gave an experimental demonstration in illustration of Professor Osborne Reynolds' researches on "Dilatancy," and was awarded a vote of thanks.

8. The following gentlemen were declared to be duly elected to the Membership of the Society:—Mr. Wm. Stevenson Brown, Iron Tube Manufacturer, 41 Oswald Street; Mr. Francis H. Underwood, U.S. Consul, 107 West Regent Street; Mr. Thomas Machell, Pianoforte and Music Seller, 39 Great Western Road; Mr. Thomas Downie, Hydepark Foundry, Finnieston Street; Mr. Alex. George Moore, M.A., B.Sc., Civil and Mining Engineer, 13 Clairmont Gardens.

9. The President announced that, in consequence of the holidays, the next Meeting of the Society would be held on Wednesday, 5th January, 1887.

(Signed) JAMES B. RUSSELL.

5th January, 1887.

The Philosophical Society of Glasgow held its Fourth Ordinary General Meeting for Session 1886-87 on the evening of the 5th January, 1887, at eight o'clock, in the Rooms of the Society, 207 Bath Street—Dr. James B. Russell, President, in the Chair.

1. The Minutes of the preceding Meeting of the Society, which were printed in the Notice calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following were admitted to the Membership of the Society:—Mr. William Stevenson Brown, Mr. Francis H. Underwood, Mr. Thomas Machell, Mr. Thomas Downie, and Mr. Alexander George Moore, M.A., B.Sc.

3. The following Candidates were proposed for election into the Society:—

Mr. D. J. F. Andrews, Electrical Engineer, Woodside Electric Works, Glasgow. Recommended by Sir William Thomson, Dr. James B. Russell, and Mr. John Mayer.

Mr. Alexander Brown, Lead Merchant, 190 Bath Street. Recommended by Mr. Daniel Monro, Mr. John Mann, and Dr. James Morton.

4. At the request of the President, the Society agreed to the suspension of the Standing Orders, so that the motion standing opposite the name of Mr. William Smart, M.A., might be submitted to the Meeting at this stage of the proceedings, as that gentleman attended under personal inconvenience and anxiety. In a few words, Mr. Smart submitted his motion, which was as follows:—"That steps be taken to form an Economical Section." The motion was seconded by Mr. Alexander Whitelaw, and unanimously adopted. Messrs. Smart, Dyer, and Whitelaw were appointed a committee to make the necessary arrangements for the formation of the Section.

5. The President announced that the Constitution creating the Glasgow and West of Scotland Technical College provided for one of the Governors of that Institution being appointed by the Council of the Philosophical Society. At their Meeting that evening the Council had unanimously elected Mr. J. J. Coleman, Vice-President of the Society, to serve in that capacity. He had no doubt that the Society would approve of the choice made by the Council, which was agreed to.

6. Mr. A. B. Kelly, Science Student, University of Glasgow, gave a short account of the "New Method of Embedding and Cutting Microscopical Sections in Paraffin." A discussion followed, in the course of which some interesting remarks were made by Dr. M'Kendrick, Mr. Fullarton, and Dr. Morton; and the thanks of the Meeting were awarded to Mr. Kelly for his communication.

7. Mr. George C. Thomson, F.C.S., then submitted "Notes on the Bursting of Leaden Water-service Pipes by Water Pressure and Frost." The paper was illustrated by numerous specimens of burst pipes. A short discussion ensued, Mr. W. P. Buchan

being the principal speaker. Mr. Thomson was awarded a hearty vote of thanks for his paper.

8. The Secretary subsequently exhibited in action and briefly described the "Foulis" Gas-Fire, which he spoke of as being a new departure in using gaseous fuel for domestic purposes. At the close of the paper, Dr. George Turner and Mr. Buchan spoke in very high terms of the value of the invention. After the awarding of the thanks of the Society to the author of the paper, many of the Members made a minute examination of the Gas-Fire exhibited.

9. The following gentlemen were declared to be duly elected to the Membership of the Society:—Mr. Walter MacLean, Lithographer, 2 Bothwell Circus; Mr. James Russell Motion, Acting Inspector of Poor, Barony Parish.

(Signed) JAMES B. RUSSELL.

19th January, 1887.

The Philosophical Society of Glasgow held its Fifth Ordinary General Meeting for Session 1886-87 on the evening of the 19th January, 1887, at eight o'clock, in the Rooms of the Society, 207 Bath Street—Dr. James B. Russell, President, in the Chair.

1. The Minutes of the preceding Meeting of the Society, which were printed in the Notice calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following were admitted to the Membership of the Society:—Mr. Walter MacLean, and Mr. James Russell Motion.

3. The following Candidates were proposed for Election into the Society:—

Mr. Adam Ker, Merchant, 175 Trongate. Recommended by Mr. James Thomson, Dr. Andrew Fergus, and Mr. John Robertson.

Mr. Andrew Stewart, Tube Manufacturer, Jordanhill House. Recommended by Dr. J. B. Russell, Mr. J. J. Coleman, and Mr. William Foulis.

Mr. James Stewart, Tube Manufacturer, 41 Oswald Street. Recommended by Dr. J. B. Russell, Mr. J. J. Coleman, and Mr. William Foulis.

Mr. James Muir, C.A., 149 West George Street. Recommended by Mr. William Smart, Dr. W. G. Blackie, and Dr. M'Gregor Robertson.

Mr. James Muirhead, Writer, 5 Eton Terrace, Hillhead. Recommended by Dr. W. G. Blackie, Mr. Walter W. Blackie, and Dr. M'Gregor Robertson.

Mr. George Handasyde Dick, Merchant, 136 Buchanan Street. Recommended by Mr. William Smart, Dr. W. G. Blackie, and Dr. M'Gregor Robertson.

Mr. Hugh Brown, Manufacturer, 5 St. John's Terrace, Hillhead. Recommended by Dr. J. B. Russell, Mr. Robert Gow, and Mr. Peter Fyfe.

Mr. Alexander Cross, Merchant, 19 Hope Street. Recommended by Mr. William Smart, Mr. Henry Dyer, and Mr. Wm. Ewing.

4. Dr. Neil Carmichael read a paper on "An Experimental Research on the Artificial Cultivation of Vaccine Lymph, with Observations on the Nature of Vaccination, and the Immunity produced by Vaccinia." A discussion followed, in which the speakers were the President, Dr. John Dougall, Dr. Joseph Coats, and Dr. John Glaister. On the motion of the President, a very cordial vote of thanks was passed to the author of the paper.

5. Mr. William Smart, M.A., submitted an Interim Report regarding the proposed Economical Section, and after some conversation on the subject he agreed, on the suggestion of the President, to convene a meeting of persons favourable to the formation of the Section, for the framing of a Constitution, appointment of Office-Bearers, etc.

6. The following gentlemen were declared to be duly elected to the Membership of the Society:—Mr. D. J. F. Andrews, Electrical Engineer, Woodside Electric Works, Glasgow; Mr. Alexander Brown, Lead Merchant, 190 Bath Street.

(Signed) JAMES B. RUSSELL.

The Philosophical Society of Glasgow held an Extra Meeting in conjunction with the Scottish Geographical Society, in the Rooms of the Society, 207 Bath Street, on the evening of Wednesday, 26th January, 1887—Mr. W. Renny Watson in the Chair.

Sir Francis de Winton, Ex-Administrator-General of the Congo Free State, read a paper on "The Congo: its Past and Present," for which he received a cordial vote of thanks, on the motion of Dr. Thomas Muir.

2nd February, 1887.

The Philosophical Society of Glasgow held its Sixth Ordinary General Meeting for Session 1886-87 on the evening of the 2nd February, 1887, at eight o'clock, in the Rooms of the Society, 207 Bath Street—Dr. James B. Russell, President, in the Chair.

1. The Minutes of the preceding Meeting of the Society, which were printed in the Notice calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following were admitted to the Membership of the Society:—Mr. D. J. F. Andrews, and Mr. Alexander Brown.

3. Mr. William Martin read a paper on "Geographical Alto-Relievo Models: their place in Education," which was very fully illustrated by examples. Dr. Thomas Muir spoke in high terms of the paper, and of the excellent work which Mr. Martin had done in furthering education in geography. The author was awarded the best thanks of the Society for his communication.

4. Mr. Arthur Kay read a paper entitled "The Aboriginal Australian, as he was," for which he was cordially thanked by the Society. A short discussion followed, in which Dr. Glaister and Dr. George A. Turner took part.

5. Mr. William Smart, M.A., reported that, in terms of the suggestion made by the President at the preceding Meeting of the Society, a meeting had been held of persons favourable to the formation of an Economic Science Section; and he submitted the following report of the proceedings of that meeting:—

A Meeting of members of the Philosophical Society interested in the proposed Economic Science Section, and of gentlemen desiring to become

Associates of the Section, was held in the Society's Rooms, on the evening of Monday, 31st January, 1887, at seven o'clock.

Mr. Wm. Smart, M.A., in the Chair.

The form of the Constitution of the Section was under consideration, and the following—based on the Constitution of the Mathematical and Physical Section—was drafted and agreed upon, subject to the approval of the Society:—

(1) The Section shall be called the *Economic Science Section.*

(2) The object of the Section shall be to aid in the advancement of Economic Science, by affording opportunities for the discussion of subjects related thereto, to be introduced by the reading of papers or by verbal communications. The general aim shall be to have the papers read before the Society, but the Section may have separate meetings for that purpose when, in the opinion of the Council of the Section, it is deemed desirable.

(3) The Section shall consist of Members of the Philosophical Society, who are to be admitted free to its meetings, and of Associates who are not Members of the Philosophical Society, who shall be admitted to the Section on payment of an Annual Subscription of Five Shillings. Associates to have the privilege of attending not only the Section's meetings, but also those meetings of the Society at which the Section's papers are read or discussed, and also of consulting the books in the Library.

(4) The management of the Section shall devolve upon a Council, consisting of a President, two Vice-Presidents, a Secretary (who shall act as Treasurer), and nine other Members.

(5) The Secretary shall be elected annually, but the term of office of the other Members of Council shall be three years. Four Members of Council shall retire annually in rotation. Retiring Members shall be eligible for re-election. Three shall be a quorum.

(In the first and second years of the Section's existence Members of Council shall decide by ballot which four shall retire.)

(6) The Office-Bearers of the Section shall be elected by the Society at its Annual Business Meeting.

(7) Vacancies occurring during the currency of a year may be filled up, *ad interim*, by the Council of the Section, if they deem it expedient.

(8) The Council of the Section shall report annually to the Society.

(9) No paper shall be read which has not been approved by the Council of the Section; and copies of the papers read shall be given into the charge of the Secretary of the Society or the Secretary of the Section, as the case may be.

(10) Associates shall be elected by the Council of the Section at any of its meetings. Each Candidate shall be recommended by two Members or Associates. The vote shall be by ballot, a majority deciding.

(11) The Associates' Annual Subscription shall become due on the First day of November in each year.

(12) No alteration shall be made upon the foregoing without the consent of the Society at two successive ordinary meetings.

The following were recommended as the first Office-bearers of the Section:—

President.

Mr. CHARLES GAIRDNER.

Vice-Presidents.

Mr. WM. SMART, M.A. | Mr. ALEXANDER CROSS.

Council.

Mr. STEPHEN MASON, M.P.	Mr. GEO. HANDASYDE DICK.
Mr. WM. EWING.	Mr. CHAS. KER, M.A., C.A.
Mr. JAS. MUIR, C.A.	Mr. JNO. MANN, jun., M.A., C.A.

Secretary and Treasurer.

Mr. WALTER W. BLACKIE, B.Sc.

It was stated by Mr. Smart that the Meeting had deemed it advisable to leave three vacancies in the nominations for the Council, which would be filled up as early as possible by the election of Associates.

After some conversation, it was agreed, on the motion of Mr. Smart, seconded by Dr. Turner, to approve of the Constitution as submitted; and the recommendation as to Office-bearers was agreed to, on the motion of Dr. Turner, seconded by Dr. Glaister.

6. The President announced that the following gentlemen had been duly elected Members of the Society:—Mr. Adam Ker, Merchant, 175 Trongate; Mr. Andrew Stewart, Tube Manufacturer, Jordanhill House; Mr. James Stewart, Tube Manufacturer, 41 Oswald Street; Mr. James Muir, C.A., 149 West George Street; Mr. James Muirhead, Writer, 5 Eton Terrace, Hillhead; Mr. George Handasyde Dick, Merchant, 136 Buchanan Street; Mr. Hugh Brown, Manufacturer, 5 St. John's Terrace, Hillhead; Mr. Alexander Cross, Merchant, 19 Hope Street.

(Signed) HENRY MUIRHEAD.

16th February, 1887.

The Philosophical Society of Glasgow held its Seventh Ordinary General Meeting for Session 1886-87 on the evening of the 16th February, 1887, at eight o'clock, in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, Past-President, in the Chair.

1. The Minutes of the preceding Meeting of the Society, which were printed in the Notice calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following were admitted to the Membership of the Society:—Mr. Adam Ker, Mr. Andrew Stewart, Mr. James Stewart, Mr. James Muir, Mr. James Muirhead, Mr. George Handasyde Dick, Mr. Hugh Brown, and Mr. Alexander Cross.

3. Mr. J. J. Coleman, F.R.S.E., F.C.S., Vice-President of the Society, gave "An Account of the Results of some Recent Experiments in Liquid Diffusion," and exhibited and described the new apparatus used in the same. An interesting discussion followed, and Mr. Coleman was awarded the thanks of the Society for his communication.

4. Dr. H. R. Mill, F.R.S.E., F.C.S., of the Scottish Marine Station for Scientific Research, read a paper on "The Physical Conditions of the Water in the Clyde Sea-Area." In the discussion which followed, Dr. John Murray (Edinburgh), and Mr. John Henderson, jun., Shipbuilder, took part. Dr. Mill was awarded the thanks of the Society for his paper; and on the motion of Mr. Coleman (who had taken the Chair), Dr. Murray was heartily thanked for his attendance, and for his interesting remarks supplementary to the paper read by Dr. Mill.

5. The Chairman announced that arrangements had been made for the delivery of the Triennial "Graham" Lecture, in connection with the Society, *on the Evening of Wednesday, 16th March*, by Professor T. E. Thorpe, F.R.S., a former member of the Society, and now of London.

(Signed) HENRY MUIRHEAD.

2nd March, 1887.

The Philosophical Society of Glasgow held its Eighth Ordinary General Meeting for Session 1886-87 on the Evening of the 2nd March, 1887, at eight o'clock, in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, Past-President, in the Chair.

1. The Minutes of the preceding Meeting of the Society, which were printed in the Notice calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Mr. Charles Gairdner delivered his Inaugural Address as President of the Economic Science Section—Subject: "An Examination of the Depression of Trade Commissioners' Report." At the close, on the motion of the Chairman, seconded by Mr. N. Dunlop, the best thanks of the Society were awarded to Mr. Gairdner.

3. Mr. John Anderson read a short paper on "The Introduction of Sea Water into Glasgow," which was illustrated by large diagrams. A discussion followed, the speakers being Mr. W. R. W. Smith, ex-Bailie Bertram, and Mr. D. M. Nelson; and Mr. Anderson received the thanks of the Society for his paper.

(Signed) JAMES B. RUSSELL.

16th March, 1887.

The Philosophical Society of Glasgow held its Ninth Ordinary General Meeting for Session 1886-87, on the evening of the 16th March, 1887, at eight o'clock, in the Large Lecture Hall of Anderson's College—Dr. J. B. Russell, President, in the Chair.

1. The Minutes of the preceding Meeting of the Society, which were printed in the Notice calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The President then announced that the occasion had been chosen for the delivery of the Third Triennial "Graham" Lecture in connection with the Chemical Section of the Society, and he resigned the Chair to Mr. J. J. Coleman, F.R.S.E., F.C.S., President of the Section, who introduced the "Graham" Lecturer, Dr. T. E. Thorpe, F.R.S., to the Meeting.

3. Dr. Thorpe proceeded with his lecture, the subject being "On certain Modern Developments of Graham's conceptions of the Essential Nature of Matter. At the close, Sir William Thomson made a few interesting remarks, and, on the motion of the Chairman, Dr. Thorpe was awarded a hearty vote of thanks.

4. Mr. Justus Widmer, Teacher, 21 Athole Gardens, was duly elected a Member of the Society.

(Signed) JAMES B. RUSSELL.

30th March, 1887.

The Philosophical Society of Glasgow held its Tenth Ordinary General Meeting for Session 1886-87 on the evening of the 30th March, 1887, at eight o'clock, in the Rooms of the Society, 207 Bath Street—Dr. J. B. Russell, President, in the Chair.

1. The Minutes of the preceding Meeting of the Society, which were printed in the Notice calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Mr. F. O. Bower, M.A., F.L.S., Regius Professor of Botany in the University of Glasgow, made two communications to the Society:—(*a*) "On the Relations of Black Ants to the Plant *Humboldtia laurifolia;*" (*b*) "On a Morphological Peculiarity in *Cordyline Australis.*" In the discussion to which they gave rise Professor Balfour, of Oxford, Dr. M'Kendrick, Mr. W. R. W. Smith, and other gentlemen took part. The best thanks of the Society were awarded to Professor Bower for his papers.

3. Dr. John Yule Mackay, of the University of Glasgow, gave an interesting sketch of the "Comparative Anatomy of the Vertebral Artery," for which he was cordially thanked by the Society.

4. The Welsbach Incandescence Gas-Light, which was exhibited during the evening, was described by Dr. William Wallace, Gas Examiner for the City of Glasgow, who also gave the results of some recent experiments made with it. A number of members put questions to Dr. Wallace, or made remarks, concerning the light. He received the best thanks of the Society.

5. The President announced that Dr. Cleland, who had undertaken to read a paper at this meeting, had been unable to attend owing to severe family affliction.

(Signed) JAMES B. RUSSELL.

13th April, 1887.

The Philosophical Society of Glasgow held its Eleventh Ordinary General Meeting for Session 1886-87 on the evening of the 13th April, 1887, at eight o'clock, in the Rooms of the Society, 207 Bath Street—Dr. J. B. Russell, President, in the Chair.

1. The Minutes of the preceding Meeting of the Society, which were printed in the Notice calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. A paper was read "On the Automatic Electric Lighting of Trains on the Underground Railway," by Mr. Thos. P. Carswell, C.E., Edinburgh, who gave an interesting demonstration of the system adopted. A discussion ensued, in which Mr. Henry S. Mavor, Mr. D. Sinclair, Mr. Henry Williams, and Mr. J. D. F. Andrews, Electrical Engineers, took part. Mr. Carswell received the thanks of the Society, and briefly replied.

2. Mr. James T. Bottomley, M.A., F.R.S.E., made some remarks on "Measurement of High Temperatures by the Air Thermometer," and briefly described a New Air Thermometer. After a few remarks by Mr. Coleman, the thanks of the Society were awarded to Mr. Bottomley.

3. Mr. J. H. Fullarton, M.A., B.Sc., read a short paper "On Biological Teaching in Germany and in this country." Dr. Stirton briefly spoke on the subject of the paper, and the author was awarded the thanks of the Society.

(Signed) JAMES B. RUSSELL.

20th April, 1887.

On the invitation of Sir William Thomson, the Society held an Extra Meeting on Wednesday, 20th April, 1887, at eight o'clock

p.m., in the Natural Philosophy Class-Room, University of Glasgow—The President in the Chair.

The following communications were made and experimentally illustrated:—1. "On a Double Chain of Electrical Measuring Instruments to measure Currents from the Millionth of a Milliampere to a Thousand Amperes, and to measure Potentials up to Forty Thousand Volts," by Sir William Thomson, F.R.S., Past-President. 2. "On Heat Radiation," by Mr. James T. Bottomley, M.A., F.R.S.E. Both gentlemen were awarded the best thanks of the Society for their communications.

(Signed) JAMES B. RUSSELL.

27th April, 1887.

The Philosophical Society of Glasgow held its Twelfth Ordinary Meeting on the evening of the 27th April, 1887, at eight o'clock, in the Rooms of the Society, 207 Bath Street. Dr. James B. Russell, President, in the Chair.

1. The Minutes of the two preceding Meetings of the Society, which were printed in the Notice calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Dr. Eben. Duncan delivered an address as President of the Sanitary and Social Economy Section. Subject:—"The Reform of our present methods of Disposal of the Dead: Earth-to-Earth Burial and Cremation." A discussion followed, in which part was taken by the Chairman, Dr. Glaister, and Messrs. W. P. Buchan, Peter Fyfe, W. R. W. Smith, Johnston Wardlaw, and Buchanan. Dr. Duncan received the thanks of the Society for his address.

3. The paper by Dr. Hay, of Pittsburg, U.S., on "Economy in the Disposal of the Dead," which was mentioned in the business notice, was held over.

4. The President announced the election of Professor Stokes, President of the Royal Society, and Professor Donders, of Utrecht,

as Honorary Members of the Society, the same having been unanimously recommended by the Council, and balloted for that evening.*

---

* The following letters have been received by the Secretary from these gentlemen, acknowledging the announcement of their election:—

LENSFIELD COTTAGE, CAMBRIDGE, *9th May*, 1887.

DEAR SIR,—I received this afternoon your letter of Saturday, announcing that the Philosophical Society of Glasgow had done me the honour of electing me an Honorary Member.

I wish, through you, to return my thanks to the Society for this favour. I feel as if I were not altogether a stranger to your Society, for your distinguished fellow, Sir William Thomson, has long been one of my intimate friends.

I am, Dear Sir,

Yours faithfully,

G. G. STOKES.

JOHN MAYER, Esq., Secretary,
Philosophical Society of Glasgow.

LENSFIELD COTTAGE, CAMBRIDGE, *24th May*, 1887.

DEAR SIR,—I write to acknowledge, with thanks, the receipt of my Diploma as Honorary Member of the Philosophical Society of Glasgow, which reached me by this morning's post.

I have already written to you to ask you to be so good as to convey my thanks to the Society.

Yours faithfully,

G. G. STOKES.

JOHN MAYER, Esq.

UTRECHT, *25th May*, 1887.

DEAR SIR,—I am much honoured by my nomination as an Honorary Member of the Philosophical Society of Glasgow, and much pleased by the contents of your letter.

Will you kindly accept my sincere thanks for yourself, and be the interpreter of my thankfulness to the President and to the Members of the Society for the great proof of their kindness.

I have the honour to be, Dear Sir,

Yours most sincerely,

DONDERS.

4th May, 1887.

An Extra Meeting of the Society (being the closing one of the Session) was held on Wednesday, 4th May, 1887, at eight o'clock p.m., in the Society's Rooms, 207 Bath Street. Dr. J. B. Russell, President, in the Chair.

1. Dr. James Colville, M.A., read a paper on "The Fourth Century Gothic Version of the Gospels, by Bishop Ulfilas, and its Value in the Study of Language." A discussion took place, the speakers being the President, Dr. Hutcheson (High School), Mr. W. Reid, M.A., Mr. G. Tamson, B.A. (Foreign Languages Master, Kelvinside Academy), and Dr. David Ross (E.C. Training College). A vote of thanks was awarded to Dr. Colville for his paper.

2. Mr. Stephen Cooke, F.C.S., communicated three papers to the Society:—(1) on "The Reducing Action of Hydrogen in contact with Platinum;" (2) on "The Action of the Electric Spark on Mixtures of Nitric Oxide with Hydrogen and other Inflammable Gases;" (3) on "The Decomposition of Nitric Oxide in contact with Water and Alkaline Solutions;" for which he received the thanks of the Society.

3. A Biographical Notice of the late Mr. Robert Gray, Vice-President of the Royal Society of Edinburgh, and Corresponding Member of the Philosophical Society of Glasgow, was received from Mr. J. B. Murdoch, and held as read. Reports from several Sections for the past Session were also received and held as read.

4. The proceedings were closed by a very cordial vote of thanks being awarded to the President for his conduct in the Chair during the Session, the proposer of the Motion being Mr. Alexander Scott.

OFFICE-BEARERS
OF THE
PHILOSOPHICAL SOCIETY OF GLASGOW.

SESSION 1886-87.

J. B. RUSSELL, B.A., M.D., LL.D., *President.*

*W. G. BLACKIE, Ph.D., LL.D., F.R.G.S.,
PROFESSOR JAMES MORTON, M.D., Pres. F.P.S.G.,
MR. J. J. COLEMAN, F.R.S.E., F.I.C., F.C.S., } *Vice-Presidents.*

PROFESSOR ROBERT GRANT, M.A., LL.D., F.R.S.,
PROFESSOR SIR WM. THOMSON, M.A., LL.D., D.C.L., F.R.S., Foreign Associate of the Institute of France, Hon. Vice-President, R.S.E., and Member of the Prussian Order *Pour le Mérite*,
ANDREW FERGUS, M.D., M.R.C.S. *Eng.*, Past-President of the Faculty of Physicians and Surgeons, Glasgow, Regius Member of the General Medical Council,
WILLIAM WALLACE, PH.D., F.R.S.E., F.I.C., F.C.S.,
HENRY MUIRHEAD, M.D., LL.D., F.F.P.S.G., } *Honorary Vice-Presidents.*

MR. JOHN ROBERTSON, *Librarian.*
MR. JOHN MANN, C.A., *Treasurer.*
MR. JOHN MAYER, *Secretary.*

MR. JAMES THOMSON, Architect, F.R.I.B.A., *Architectural Section*,
PROFESSOR JOHN CLELAND, M.D., LL.D., D.Sc., F.R.S., *Biological Section*,
Mr. J. J. COLEMAN, F.R.S.E., F.I.C., F.C.S., *Chemical Section*,
EBEN. DUNCAN, M.D., F.F.P.S.G., *Sanitary and Social Economy Section*,
W. G. BLACKIE, PH.D., LL.D., F.R.G.S., *Geographical and Ethnological Section*,
SIR WILLIAM THOMSON, F.R.S., &c., *Mathematical and Physical Section*,
MR. CHARLES GAIRDNER, *Economic Science Section*, } *Presidents of Sections.*

Other Members of Council.

*MR. ALEXANDER WHITELAW.
*MR. A. LINDSAY MILLER.
*J. M'GREGOR ROBERTSON, M.A., M.B., C.M.
*MR. ROBERT GOODWIN, C.E.
PROFESSOR WILLIAM DITTMAR, LL.D., F.R.SS., *L. and E.*, &c.
MR. WILLIAM RENNY WATSON.
MR. ROBERT FRANKLIN MUIRHEAD, M.A., B.Sc.
MR. JAMES L. MITCHELL.
PROFESSOR JOHN GRAY M'KENDRICK, M.D., LL.D., F.R.S., F.R.S.E., F.R.C.P.E.
MR. HENRY DYER, M.A., B.Sc., C.E.
MR. WILLIAM MILNE, M.A., B.Sc., F.R.S.E.
GEORGE A. TURNER, M.D.

* *Retire by rotation in November, 1887.*

COMMITTEES APPOINTED BY THE COUNCIL.

COMMITTEE ON FINANCE.

DR. J. B. RUSSELL, *President.*

MR. JAMES L. MITCHELL.	MR. A. WHITELAW.
MR. R. GOODWIN.	MR. A. LINDSAY MILLER.

MR. JOHN MANN, *Treasurer, Convener.*

MR. J. J. COLEMAN, *V.-P., Sub-Convener.*

COMMITTEE ON PAPERS.

DR. J. B. RUSSELL, *President.*

DR. W. G. BLACKIE,
DR. JAMES MORTON, } *Vice-Presidents.*

MR. J. J. COLEMAN.	MR. JAMES THOMSON.
DR. M'G. ROBERTSON.	MR. HENRY DYER.

PROFESSOR M'KENDRICK, *Convener.*

COMMITTEE ON THE LIBRARY.

DR. J. B. RUSSELL, *President.*

DR. W. G. BLACKIE,
DR. JAMES MORTON,
MR. J. J. COLEMAN, } *Vice-Presidents.*

MR. R. F. MUIRHEAD.	PROFESSOR CLELAND.
MR. JAMES L. MITCHELL.	MR. R. GOODWIN.
DR. EBEN. DUNCAN.	DR. MUIRHEAD.
MR. A. WHITELAW.	MR. JAMES THOMSON.
MR. W. RENNY WATSON.	MR. HENRY DYER.

MR. JOHN ROBERTSON, *Librarian, Convener.*

HOUSE COMMITTEE.

Consisting of Members of the Philosophical Society and of the Institution of Engineers and Shipbuilders.

Institution of Engineers and Shipbuilders.	*Philosophical Society.*
MR. A. C. KIRK.	DR. HENRY MUIRHEAD.
MR. WM. FOULIS.	DR. WM. WALLACE.
MR. JOHN WARD.	MR. ARCHIBALD ROBERTSON.

OFFICE-BEARERS OF SECTIONS.

ARCHITECTURAL SECTION.

Mr. JAMES THOMSON, Architect, F.R.I.B.A., *President.*

Mr. T. L. WATSON, Architect,
Mr. ALEXANDER MUIR, Builder, } *Vice-Presidents.*

Mr. JAMES HOWATT, Measurer, *Treasurer.*

Mr. A. LINDSAY MILLER, Architect, 121 West Regent Street, *Secretary.*

Members of Council.

Mr. JAMES SELLARS, Architect.
Mr. DAVID THOMSON, Architect.
Mr. WILLIAM LANDLESS, Architect.
Mr. THOMAS GILDARD, Architect.
Mr. JAMES CHALMERS, Architect.
Mr. R. A. M'GILVRAY, Plasterer.
Mr. WILLIAM GILFILLAN, Marble-cutter.
Mr. JOHN DANSKEN, Measurer.
Mr. WILLIAM HOWATT, Measurer.
Mr. WILLIAM CAIRNS, Plumber.

CHEMICAL SECTION.

President.

Mr. J. J. COLEMAN, F.R.S.E., F.I.C., F.C.S.

Permanent Vice-Presidents.

PROFESSOR FERGUSON, M.A., LL.D., F.I.C., F.C.S.
Mr. E. C. C. STANFORD, F.C.S.
Mr. R. R. TATLOCK, F.R.S.E., F.I.C., F.C.S.
WILLIAM WALLACE, Ph.D., F.R.S.E., F.I.C., F.C.S.

Elected Vice-Presidents.

JOHN CLARK, Ph.D., F.I.C., F.C.S.
Mr. ALEXANDER WHITELAW.
Mr. G. G. HENDERSON, M.A., B.Sc.

Committee.

Mr. R. T. THOMSON.
Mr. A. WHITELAW.
Mr. T. N. WHITELAW.
PROFESSOR DITTMAR, LL.D., F.R.S.
Mr. WILLIAM LANG, jun.
Mr. W. J. CHRYSTAL, F.C.S.
Mr. C. HOPE.
Mr. JOHN MAYER.
Mr. JAMES PARK.

Hon. Treasurer.

Dr. WALLACE, City Analysts' Laboratory, 138 Bath Street.

Hon. Secretary.

Mr. JOHN TATLOCK, 100 Sauchiehall Street.

BIOLOGICAL SECTION.

PROFESSOR JOHN CLELAND, M.D., LL.D., D.Sc., F.R.S., *President.*

HENRY E. CLARK, M.R.C.S.,
JOHN BARLOW, M.D., F.R.C.S., } *Vice-Presidents.*

J. YULE MACKAY, M.D., *Secretary and Treasurer,*
University of Glasgow.

Members of Council.

CHARLES CAMERON, M.D., LL.D., M.P.
JAMES CHRISTIE, A.M., M.D.
MR. W. MILNE, M.A., F.R.S.E.
PRINCIPAL M'CALL, F.R.C.V.S.
DAVID NEWMAN, M.D.
J. M'GREGOR ROBERTSON, M.A., M.B.
JAMES STIRTON, M.D., F.L.S.
MR. JAMES THOMSON, F.G.S.
REV. A. S. WILSON, M.A., B.Sc.

SANITARY AND SOCIAL ECONOMY SECTION.

DR. EBEN. DUNCAN, *President.*

MR. W. P. BUCHAN,
DR. CHRISTIE, } *Vice-Presidents.*

MR. W. R. M. CHURCH, C.A., *Secretary,*
75 St. George's Place.

Members of Council.

DR. FERGUS.
MR. J. CLELAND BURNS.
MR. W. R. W. SMITH.
MR. H. K. BROMHEAD.
MR. A. FREW, C.E.
DR. NEIL CARMICHAEL.
DR. JOHN GLAISTER.
MR. JOHN YOUNG.
MR. DAVID BARCLAY.
MR. PETER FYFE.
MR. WALTER ARROL.
MR. ALEXANDER SCOTT.

GEOGRAPHICAL AND ETHNOLOGICAL SECTION.

W. G. BLACKIE, Ph.D., LL.D., F.R.G.S., *President.*

SIR MICHAEL CONNAL,
THOMAS MUIR, M.A., LL.D., F.R.S.E., } *Vice-Presidents.*
MR. JAMES STEVENSON, F.R.G.S.,

GEO. A. TURNER, M.D., C.M., 1 Clifton Place, Sauchiehall Street,
Secretary and *Treasurer.*

Members of Council.

DR. JAMES CHRISTIE, A.M.
MR. WILLIAM EWING.
MR. NATHANIEL DUNLOP.
MR. ROBERT GOW.
MR. JAMES GRIERSON.
MR. MAXWELL HANNAY.
MR. WILLIAM KER.
MR. JACQUES VAN RAALTE.
MR. ALEXANDER SCOTT.
MR. W. RENNY WATSON.
MR. ARTHUR KAY.
MR. ROBERT BLYTH, C.A.

MATHEMATICAL AND PHYSICAL SECTION.

SIR WILLIAM THOMSON, LL.D., D.C.L., &c., *President.*

THOMAS MUIR, M.A., LL.D., F.R.S.E.,
PROF. ROBERT GRANT, M.A., LL.D., F.R.S., } *Vice-Presidents.*

ROBERT FRANKLIN MUIRHEAD, M.A., B.Sc., *Secretary and Treasurer*, 22 Arlington Street.

Members of Council.

Mr. PETER ALEXANDER, M.A.
PROFESSOR JAMES BLYTH, M.A.
Mr. JAMES T. BOTTOMLEY, M.A.
Mr. HENRY DYER, M.A., B.Sc., C.E.
PROFESSOR WILLIAM JACK, M.A., LL.D.
PRINCIPAL ANDREW JAMIESON, F.R.S.E., C.E.
PROFESSOR JAMES THOMSON, LL.D., F.R.S.
Mr. WILLIAM RENNY WATSON.
Mr. JAMES WOOD, M.A.

ECONOMIC SCIENCE SECTION.

Mr. CHARLES GAIRDNER, *President.*

Mr. ALEXANDER CROSS,
Mr. WILLIAM SMART, M.A., } *Vice-Presidents.*

Mr. WALTER W. BLACKIE, B.Sc., *Secretary and Treasurer.*

Members of Council.

Mr. WILLIAM EWING.
Mr. GEORGE HANDASYDE DICK.
Mr. CHARLES KER, M.A., C.A.
Mr. JOHN MANN, jun., M.A., C.A.
Mr. STEPHEN MASON, M.P.
Mr. JAMES MUIR, C.A.

ADDITIONS TO THE LIBRARY.

Donations in addition to the Works received in Exchange from the Societies, &c., named on pages 441-444.

DONATIONS.	PRESENTED BY
Fifth Annual Report of the U.S. Geological Survey. 1883-84. 4to. Washington, 1885, .	The U.S. Geological Survey.
Observations of the International Polar Expedition. 1882-83. Fort Rae. 4to. London, 1886, ...	The Meteorological Office.
Vital Statistics of the City of Glasgow. Parts 2, 3. 1886, ...	Dr. J. B. Russell.
The Children of the City—What can we do for them? Pamphlet. Edinburgh, 1886, . .	,,
Observations and Researches made at the Hong-Kong Observatory. 1885-86. F'cap folio. Hong-Kong, 1886, ...	Hong-Kong Observatory.
Report of the Entomologist for 1885. Pamphlet. Ottowa, 1886, ...	James Fletcher.
Report of the British Association—Aberdeen Meeting, 1885, ...	The Association.
Canadian Economics—Montreal Meeting, 1884,	,,
Hocus Pocus; or, The Whole Art of Legerdemain in Perfection. By H. Dean. 4to. Glasgow, 1886, ...	John Anderson.
An Introduction to the Differential and Integral Calculus. By W. J. Millar. 12mo. London,	The Author.
Paper on some properties of Cast-iron and other Metals. By W. J. Millar. 8vo Pamphlet. 1886, ...	,,
What I Believe. By Leon Tolstoi. 8vo. London, 1885, ...	,,
Centaire de M. Chevreul, 31st August, 1886. 4to. Paris, ...	M. Chevreul.
Jouillet's Elements de Physique. 2 vols. 8vo. Paris, 1856, ...	Dr. Thomas Reid.
Serret's Cours de Calcul Différentiel et intégral. 2 vols. 8vo. Paris, 1868, ...	,,
Boucharlat's Elements de Mechanique. Second edition. 8vo. Paris, 1827, ...	,,

DONATIONS.	PRESENTED BY
Lamé's Leçons sur les Coordonnées Curvilignes. 8vo. Paris, 1859,	Dr. Thomas Reid.
Specifications of Patents:—	
Preparations of India-rubber and Gutta-percha. Part II.,	The Commissioners of Patents.
Drains and Sewers, Sewage and Manure. Part II.,	,,
Photography. Part III.,	,,
Metals and Alloys (excepting Iron and Steel). Part I.,	,,
Agriculture. Division III. Agriculture and Traction Engines,	,,
Railways. Part II.,	,,
Firearms and Ammunition, &c. Divisions I., II. Part III.,	,,
Artificial Leather, Floorcloth, Oilcloth, &c. Part II.,	,,
Preparing and Cutting Cork, Bottling Liquids, &c. Parts II., III.,	,,
Starch, Gum, Size, Glue, and other Stiffening, &c. Parts I., II.,	,,
Clinical Manual for the Study of Medical Cases. Second edition. By Dr. Finlayson. 8vo. London, 1886,	The Author.
Proceedings of American Association for the Advancement of Science. Philadelphia Meeting, 1884. 8vo. Salem, 1885,	Dr. Muirhead.
Canada under the National Policy. Arts and Manufactures. 8vo. Montreal, 1883,	Dr. Turner.
Canada—Its History, Productions, and National Resources. 8vo. Ottawa, 1886,	,,
Red River. By J. J. Hargrave. 8vo. Montreal, 1871,	,,
To Canada with Emigrants. By T. E. Ritchie. 8vo. London, 1885,	,,
England and Canada. By S. Fleming. 8vo. London, 1884,	,,
Our Railway to the Pacific. By the Marquis of Lorne. 8vo. Pamphlet. London, 1886,	,,
Handbook of Birmingham. 1886,	Dr. Muirhead.
Vestiges of the Natural History of Creation. Ninth edition. 12mo. London, 1851,	,,
Autobiography of John Stuart Mill. 8vo. London, 1873,	,,
A New Philosophical Theory of the Sun. By H. R. Rogers. Pamphlet. Buffalo, 1886,	The Author.
International Monetary Conference, held in Paris, 1878. 8vo. Washington, 1879,	James Mavor.

DONATIONS.	PRESENTED BY
The Position of Law in the Doctrine of Money. By S. D. Horton. Pamphlet. London, 1882,	James Mavor.
Address on the Interest of the United States in the Silver Question. By S. D. Horton. Pamphlet. London, 1882, ...	,,
The Quarterly Journal of Economics. Vol. I. Part I. October, 1886. 8vo. Boston, 1886,	,,
Burgh of Stirling. Extract from Records, 1519-1666. 4to. Glasgow, 1887, ...	The Stirlingshire Society and Sons of the Rock.
The Castellated and Domestic Architecture of Scotland. By D. Macgibbon and T. Ross. 2 vols. 8vo. Edinburgh, 1887, . . .	The Architectural Section.
Contributions to Meteorology. By Elias Loomis. 4to. Newhaven, 1887, ...	The Author.
Electric Meteorology. By G. A. Rowall. Pamphlet. Oxford, 1887, ...	,,
Student's Catalogue. Glasgow University Library. Glasgow, 1887, ...	The College Librarian.
Meteorological Observations for 1886. Rousdon Observatory, Devon, ...	The Observatory.
Report of the Board of Technical Education of New South Wales. 1885, ...	The Board.
On the Fossil Plants of the Laramie Formations of Canada. By W. J. Dawson. Pamphlet. 1886, ...	The Author.
The Artificial Cultivation of Vaccine Lymph. By Dr. John Dougall. Pamphlet. Glasgow, 1886, ...	,,

BOOKS BOUGHT.

Möbius Werke. Vol 3. 8vo. Leipzig, 1886.

Microbes, Ferments, and Moulds. By E. L. Trouessant. 8vo. London, 1886.

Scotland in Pagan Times. The Bronze and Stone Ages. By Joseph Anderson. 8vo. Edinburgh, 1886.

Hazell's Annual Cyclopædia. 1886-87. 8vo. London.

La Nature. 1886.

Jahres Bericht der Chemischen Technologie. 1885. 8vo. Leipzig.

The Mammalia in relation to Primeval Times. By Oscar Schmidt. 8vo. London, 1885.

Mineral Statistics for 1885.

Encyclopædia Americana. Vol. 3. 4to. Philadelphia, 1886.

British Fungi. Hymenomycetes. Vol. 2. By John Stevenson. 8vo. Edinburgh, 1886.

Life of Sir Robert Christison, Bart. Vol. 2. 8vo. Edinburgh.

Notes and Jottings from Animal Life. By Frank Buckland. 8vo. London, 1886.

British Colonies and their Resources. By James Bonwick. 8vo. London, 1886.

Geology: Chemical, Physical, and Stratigraphical. Vol. 1. Chemical and Physical. By Joseph Prestwich. 8vo. Oxford, 1886.

Elements of Chemical Physics. By Josiah Cooke. 8vo. London, 1886.

Commercial Organic Analysis. Vol. 2. By Alfred H. Allen. 8vo. London, 1886.

A History of the Theory of the Elasticity and Strength of Materials. Vol. 1. By J. Todhunter. 8vo. Cambridge, 1886.

Text-Book of Entomology. By W. F. Kirby. 8vo. London, 1885.

The Function of the Brain. By David Ferrier. 2nd edition. 8vo. London, 1886.

Steam and Steam Engines. By A. Jamieson. 8vo. London, 1886.

The Primeval World of Switzerland. By Heer. 2 vols. 8vo. London, 1886.

Pre-History of the North. By J. J. A. Worsaaes. 8vo. London, 1886.

A Treatise on Chemistry. By Roscoe and Schorlemmer. Vol. III. Part 3. Organic Chemistry. 8vo. London, 1886.

Dictionary of Biography. Vols. 7, 8, 9.

The Geographical and Geological Distribution of Animals. International Series.

Rust, Smut, Mildew, and Mould. By M. C. Cooke. 12mo. London, 1886.

A Popular History of Astronomy. By A. M. Clerk. 8vo. Edinburgh, 1885.

Handbook of Practical Botany. By Strasburger and Hillhouse. London, 1887.

The Age of Electricity. By Benjamin Park.

The Chemistry of the Sun. By J. N. Lockyer. 8vo. London, 1887.

Letters and Journal of W. S. Jevons. 8vo. London, 1886.

The Mechanics of Machinery. By A. B. W. Kennedy. 8vo. London, 1886.

Three Years of Arctic Service. By A. W. Greely. 2 vols. 8vo. London, 1886.

Spectrum Analysis. By Sir H. E. Roscoe. 8vo. London, 1885.

An Arctic Province—Alaska and the Seal Islands. By H. W. Elliott. 8vo. London, 1886.

On Light. By G. G. Stokes. 8vo. London, 1885.

Practical Electricity. By W. E. Ayrton. 8vo. London, 1887.

The Science of Thought. By F. Max Müller. 8vo. London, 1887.

Lives of the Electricians. By W. T. Jeans. 8vo. London, 1887.

Politischen Oekonomie. By Schönberg Gustav. 3 vols. 8vo. Tubingen, 1885-6.

Fortschrifte der Mathematik. By Ohrtmann. Vol. 16.

The Far Interior. By W. M. Kerr. 2 vols. 8vo. London, 1886.

Palæontographical Society's Publications for 1886:—

Fossil Sponges. Part 1.

Jurassic Gasteropoda. Part 1. No. 1.

Inferior Oolite Ammonites. Part 1.

Pleistocene Mammalia. Part 6.

THE PHILOSOPHICAL SOCIETY EXCHANGES WITH THE FOLLOWING SOCIETIES, &c.:—

Aberdeen Philosophical Society,	Aberdeen.
Academia Real Das Sciencias de Lisboa,	Lisbon.
Academy of Natural Sciences of Philadelphia,	Philadelphia.
Academy of Science,	Connecticut.
Academy of Science,	St. Louis.
American Academy of Arts and Sciences,	Boston.
American Geographical Society,	New York.
American Pharmaceutical Society,	Philadelphia.
American Philosophical Society,	,,
Anthropological Institute,	London.
Astor Library, New York,	New York.
Library of Royal Observatory,	Melbourne.
Bath Natural History and Antiquarian Field Club,	Bath.
Belfast Natural History and Philosophical Society,	Belfast.
Berwickshire Naturalists' Club,	Alnwick.
Biblical Archæology,	London.
Birkenhead Literary and Scientific Society,	Birkenhead.
Birmingham Philosophical Society,	Birmingham.
Boston Natural History Society,	Boston.
Boston Public Library,	,,
Botanical Society of Edinburgh,	Edinburgh.
Bremen Geographical Society,	Bremen.
Bristol Naturalists' Society,	Bristol.
Buffalo Society of Natural Sciences,	Buffalo.
Bureau Scientifique Central Nèerlandais,	Harlem.
California Academy of Sciences,	California.
Cambridge Philosophical Society,	Cambridge.
Canadian Institute,	Canada.
Canadian Society of Civil Engineers,	Montreal.
Cardiff Naturalists' Society,	Cardiff.
Chemical Society,	London.
Cleveland Institution of Engineers,	Middlesborough.
Commissioners of Patents,	London.
Davenport Academy of Natural Sciences,	Davenport, Iowa.
Deutscher Kolonial Verein,	Berlin.
Die Deutsche Chemische Gesellschaft,	,,
Dublin University Biological Association,	Dublin.
École Polytechnique,	Paris.
Edinburgh Geological Society,	Edinburgh.
Engineering,	London.
Entomological Society of Ontario,	London, Ontario.
Epping Forest and County of Essex Naturalists' Field Club,	Buckhurst Hill, Essex.
Folkestone Natural History Society,	Folkestone.
Franklin Institute,	Philadelphia.
Geographical Society,	Geneva.

Geographical Society of Australasia,	Sydney.
Geographical Society of Scotland,	Edinburgh.
Geographische Gesellschaft zu Griefswald,	Griefswald.
Geological Society of Glasgow,	Glasgow.
Geological Survey of Canada,	Montreal.
Geological Survey of India,	Calcutta.
Glasgow Archæological Society,	Glasgow.
Hamburg Geographical Society,	Hamburg.
Hertfordshire Natural History Society and Field Club,	Watford, Herts.
Historic Society of Lancashire and Cheshire,	Liverpool.
Institut Canadien-Français d'Ottawa,	Ottawa.
Institution of Civil Engineers,	London.
Institution of Engineers and Shipbuilders in Scotland,	Glasgow.
Institution of Mechanical Engineers,	London.
Insurance and Actuarial Society of Glasgow,	Glasgow.
John Hopkins University,	Baltimore.
Kasan Imperial University,	Kasan.
Kon. Akademie van Wetenschappen,	Amsterdam.
Leicester Literary and Philosophical Society,	Leicester.
Literary and Historical Society of Quebec,	Quebec.
Literary and Philosophical Society of Leeds,	Leeds.
Literary and Philosophical Society of Liverpool,	Liverpool.
Literary and Philosophical Society of Manchester,	Manchester.
Liverpool Engineering Society,	Liverpool.
Liverpool Geological Society,	,,
Liverpool Naturalists' Field Club,	,,
Liverpool Polytechnic Society,	,,
London Geological Society,	London.
Manchester Association of Employers, Foremen, &c.,	Manchester.
Manchester Geographical Society,	,,
Manchester Scientific Students' Association,	,,
Manitoba Historical and Scientific Society,	Winnipeg.
Mechanical World,	London.
Meteorological Observatory,	Montsouris, Paris.
Middlesex Hospital,	London.
Midland Institute of Mining Engineers,	Barnsley.
Midland Medical Miscellany,	Leicester.
Mining Institute of Scotland,	Hamilton.
Mitchell Library,	Glasgow.
Musée Teyler,	Harlem.
National Academy,	Washington.
National Observatory,	,,
Natural History Society of Glasgow,	Glasgow.
Naturalists' Union,	Huddersfield.
Netherlands Geographical Society,	Amsterdam.
New York Academy of Sciences,	New York.
New Zealand Institute,	Wellington.
North of England Institute of Mining and Mechanical Engineers,	Newcastle-on-Tyne.

N. Staffordshire Institute of Mining and Mechanical Engineers,	London.
Observatoire Royal de Bruxelles,	Bruxelles.
Odontological Society,	London.
Ohio Mechanics' Institute,	Cincinnati.
Oneida Historical Society,	Utica.
Paisley Public Library,	Paisley.
Pharmaceutical Society,	London.
Photographic Society,	,,
Philadelphia Alumni Association,	Philadelphia.
Physical Society of London,	London.
Physico-Chemical Society, University of St. Petersburg,	St. Petersburg.
Powys-land Club,	Liverpool.
Publisher of "Engineering,"	London.
Registrar-General,	Melbourne.
Royal Academy of Science,	Brussels.
Royal Academy of Science,	Stockholm.
Royal Astronomical Society,	London.
Royal Cornwall Polytechnic Society,	Falmouth.
Royal Dublin Society,	Dublin.
Royal Geographical Society,	London.
Royal Geographical Society,	Vienna.
Royal Institute of British Architects,	London.
Royal Institute of Lombardy,	Milan.
Royal Institution of Cornwall,	Truro.
Royal Institution of Great Britain,	London.
Royal Irish Academy,	Dublin.
Royal Microscopical Society,	London.
Royal Physical Society of Edinburgh,	Edinburgh.
Royal Prussian Academy of Science,	Berlin.
Royal Scottish Society of Arts,	Edinburgh.
Royal Society of Canada,	Quebec.
Royal Society of Edinburgh,	Edinburgh.
Royal Society of London,	London.
Royal Society of Tasmania,	Hobart Town.
Royal Society of Victoria,	Melbourne.
School of Mines,	New York.
Science,	Cambridge, Mass.
Science Monthly,	London.
Scottish Geographical Society,	Edinburgh.
Scottish Meteorological Society,	,,
Seismological Society of Japan,	Tokio.
Smithsonian Institution,	Washington.
Social Science Association,	London.
Society for Psychical Research,	London.
Société des Sciences Physiques et Naturelles,	Bordeaux.
Société Royal des Sciences de Liége,	Liége.
Society of Arts,	London.

Society of Chemical Industry,	London.
Society of Engineers,	,,
South Wales Institute of Engineers,	Swansea.
Statistical Society,	London.
United States Geologist,	Washington.
United States Observatory,	,,
United States Survey,	,,
University of Christiania,	Christiania.
University of Tokio, Japan,	Tokio, Japan.
Verein für Erdkunde zu Halle,	Halle.
Videnskabs-Selskabet i Christiania,	Christiania.
Washburn Observatory—University of Wisconsin,	Washburn.
Wagner Free Institute of Science,	Philadelphia.

LIST OF PERIODICALS.

WEEKLY.

Academy.
Architect.
Athenæum.
British Architect.
British Journal of Photography.
British Medical Journal.
Builder.
Building News.
Chemical News.
Comptes Rendus.
Dingler's Polytechnisches Journal.
Economist.
Electrician.
Engineer.
Engineering.
English Mechanic.
Industries.
Iron.
Journal of the Society of Arts.
Journal of Gas Lighting.
Mechanical World.
Nature.
Notes and Queries.
Pharmaceutical Journal.
Science.
Scientific American.
Telegraphic Journal.

FORTNIGHTLY.

Berichte der Deutschen Chemischen Gesellschaft.
Bulletin de la Société Chimique de Paris.
Journal für Praktische Chemie.
Zeitschrift für die Chemische Industrie.

MONTHLY.

American Journal of Science and Arts.
Annales de Chimie et de Physique.
Annales des Ponts et des Chaussées.
Annales des Sciences Naturelles—Botanique.
Annales des Sciences Naturelles—Zoologie.
Bulletin de la Société d'Encouragement.
Bulletin de la Société Géologique de France.
Bulletin Mensuel de l'Observatoire de Montsouris.
Canadian Entomologist.
Chamber of Commerce Journal.

Entomologist.
Entomologists' Monthly Magazine.
Geological Magazine.
Hardwicke's Science Gossip.
Journal of the Franklin Institute.
Journal de Pharmacie et de Chimie.
Journal of Botany.
Monthly Notes of the Library Association.
Journal of the Photographic Society.
Journal of Science.
Journal of the Chemical Society.
Annalen der Chemie.
Annalen der Physik und Chemie.
Annals and Magazine of Natural History.
Analyst.
Antiquary.
Beiblätter zu den Annalen der Physik und Chemie.
Journal of the Scottish Geographical Society.
London, Edinburgh, and Dublin Philosophical Magazine.
Midland Medical Miscellany.
Midland Naturalist.
Monatsbericht der Königlich Preussischen Akademie der Wissenschaften zu Berlin.
Odontological Society's Transactions.
Proceedings of Royal Society of London.
Proceedings of Royal Geographical Society.
Royal Astronomical Society's Monthly Notices.
Sanitary Journal.
Science Monthly.
Zoologist.

QUARTERLY.

Annales des Mines.
Bulletin de la Société Industrielle de Mulhouse.
Grevillea.
Journal of Anatomy and Physiology.
Journal of the Royal Agricultural Society of England.
Journal of the Scottish Meteorological Society.
Journal of the Statistical Society.
Mind: a Quarterly Review of Psychology and Philosophy.
Quarterly Journal of Economics.
Quarterly Journal of Geological Society.
Quarterly Journal of Microscopical Science.
Quarterly Journal of Ornithology.
Quarterly Journal of Pure and Applied Mathematics.
Revue Universelle des Mines.
Scientific Roll.
Zeitschrift für Analytische Chemie.

LIST OF MEMBERS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW,

FOR 1886-87.

HONORARY MEMBERS.

(Limited to Twenty.)

WITH YEAR OF ELECTION.

FOREIGN.

	Michael Eugene Chevreul, Paris,	1860
	Hermann Ludwig Ferdinand von Helmholtz, Berlin,	1860
	Rudolph Albert Kölliker, Würtzburg,	1860
	Wilhelm Weber, Göttingen,	1860
5	Ernst Heinrich Hæckel, Jena,	1880
	Louis Pasteur, Paris,	1885
	Franz Cornelius Donders, Utrecht,	1887

AMERICAN AND COLONIAL.

	James Dwight Dana, LL.D., Professor of Geology and Mineralogy in Yale College, Connecticut,	1860
	Elias Loomis, Professor of Natural Philosophy, Yale College, Connecticut,	1860
10	Robert Lewis John Ellery, F.R.A.S., Victoria,	1874
	Sir John William Dawson, LL.D., F.R.S., Principal of Macgill College, Montreal,	1883
	Asa Gray, LL.D., D.C.L., Professor of Natural History in Harvard University,	1885

BRITISH.

	James Prescott Joule, LL.D., D.C.L., F.R.S., Manchester,	1860
	Sir Andrew Crombie Ramsay, LL.D., F.R.S., London,	1874
15	Sir Joseph Dalton Hooker, K.C.B., K.C.S.I., M.D., D.C.L., LL.D., F.R.S., Kew,	1874
	Thomas Henry Huxley, Ph.D., LL.D., D.C.L., F.R.S., London,	1876
	Herbert Spencer, London,	1879
	John Tyndall, LL.D., D.C.L., F.R.S., M.R.I., London,	1880
	Rev. John Kerr, LL.D., Glasgow,	1885
20	George Gabriel Stokes, M.A., LL.D., D.C.L., *P.*, R.S., Cambridge,	1887

CORRESPONDING MEMBERS.

WITH YEAR OF ELECTION.

Rev. H. W. Crosskey, LL.D., F.G.S., 117 Gough road, Birmingham, . . . 1874
A. S. Herschel, B.A., F.R.S., F.R.A.S., Professor of Physics, College of Science, 16 Saville row, Newcastle-on-Tyne, ... 1874
Thomas E. Thorpe, Ph.D., F.R.S., Royal School of Mines, London, . . . 1874
John Aitken, F.R.S.E., Darroch, Falkirk, ... 1883
5 Alex. Buchan, M.A., F.R.S.E., Secretary to the Scottish Meteorological Society, 73 Northumberland street, Edinburgh, ... 1883
James Dewar, M.A., F.R.S., L. & E., M.R.I., Jacksonian Professor of Physics, University of Cambridge, and Professor of Chemistry in the Royal Institution of Great Britain, Cambridge, ... 1883
Stevenson Macadam, Ph.D., F.R.S.E., Lecturer on Chemistry, Surgeons' Hall, Edinburgh, ... 1883
Joseph Swan, Newcastle-on-Tyne and London, ... 1883
E. A. Wünsch, F.G.S., London, ... 1883
10 George Anderson, Master of the Mint, Melbourne, ... 1885

ORDINARY MEMBERS.

WITH YEAR OF ENTRY.

* *Denotes Life Members.*

Adam, William, M.A., 415 Sauchiehall street. 1876
Addie, John, 144 St. Vincent street. 1861
Aikman, C. M., M.A., B.Sc., F.C.S., 183 St. Vincent street. 1886
Alexander, Peter, M.A., 16 Smith street, Hillhead. 1885
5 Alexander, Thos., 8 Sardinia terrace. 1869
Alley, Stephen, Sentinel Works, Polmadie road. 1884
Anderson, Alexander, 157 Trongate. 1869
Anderson, James Hackson, Wardlawhill, Rutherglen. 1885
Anderson, John, 22 Ann street. 1884
10 *Anderson, T. M'Call, M.D., Professor of Clinical Medicine in the University of Glasgow, 2 Woodside terrace. 1873
Anderson, W. F. G., 47 Union street. 1878
Andrews, D. J. F., Electric Works, Woodside. 1887
Arnot, James Craig, 162 St. Vincent street. 1869
Arrol, Archibald, 16 Dixon street. 1869
15 Arrol, Walter, 16 Dixon street. 1869
Arrol, William A., 16 Dixon street. 1869

Bain, Sir James, F.R.S.E., 3 Park terrace. 1866
Bain, Robert, 132 West Nile street. 1869
Baird, Alex. Smith, 26 Sardinia terrace, Hillhead. 1870
20 Ball, Henry W., Averley, Hillhead. 1875
Balloch, Robert, 131 St. Vincent street. 1843
Balmain, Thos., 1 Kew terrace, Kelvinside. 1881
Barclay, James, 36 Windsor terrace. 1871
Barclay, John, 37 Monteith row. 1882
25 Barlow, John, M.D., Lecturer on Physiology in Royal Infirmary School, 27 Elmbank crescent. 1880
Barnett, Hugh, Elmwood, Crosshill. 1883
Baronsfeather, W. N., Rosebank, Mansewood, Pollokshaws. 1880
Barrett, Francis Thornton, Mitchell Library. 1880
*Barr, James, C.E., I.M., 132 West Regent street. 1883
30 Barr, Thos., M.D., F.F.P. & S.G., 7 Albany place. 1879
Bayne, A. Malloch, 1 Hamilton terrace, Partick. 1878
Beatson, George T., B.A. Cantab., M.D., 2 Royal crescent. 1881
Begg, Wm., 636 Springfield road. 1883
*Beith, Gilbert, 7 Royal Bank place. 1881
35 Bell, Dugald, 27 Lansdowne crea. 1871
*Bell, Henry, 5 Cornwall terrace, Regent's Park, London, N.W. 1876
Bell, James, 7 Marlborough terrace, Kelvinside. 1877
Bennett, Robert J., 8 Holland place. 1883
Binnie, J., 69 Bath street. 1877
40 Binnie, Robert, Ashbourne, Gourock. 1881
Black, Adam Elliot, C.A., F.C.S., 5 Hillsborough square, Bruce st., Hillhead. 1880
Black, D. Campbell, M.D., M.R.C.S.E., 50 Woodlands road. 1872
Black, J. Albert. Duneira, Row. 1869
Black, John, 16 Park terrace. 1869
45 Black, Malcolm, M.B., C.M., 5 Canning place. 1880

*Blackie, J. Alexander, 17 Stanhope street. 1881
*Blackie, J. Robertson, 17 Stanhope street. 1881
Blackie, Robert, 17 Stanhope st. 1847
Blackie, W. G., Ph.D., F.R.G.S., 17 Stanhope street. 1841
Blackie, Walter W., B.Sc., 1 Belhaven terrace. 1886
Blair, G. M'Lellan, 2 Lilybank terrace. 1869
Blair, J. M'Lellan, 2 Bute Gardens, Hillhead. 1869
Blyth, James, M.A., F.R.S.E., Professor of Mathematics and Natural Philosophy in Anderson's College. 1881
*Blyth, Robert, C.A., 1 Montgomerie quadrant. 1885
Bost, David Ashton, 60 New Sneddon, Paisley. 1884
Bost, Timothy, 33 Renfield street. 1876
Bottomley, James T., M.A., F.R.S.E., F.C.S., Demonstrator in Natural Philosophy, University of Glasgow, 13 University gardens, Hillhead. 1880
Bottomley, Wm., Junr., C.E., University. 1880
Boucher, J., I.A., 247 St. Vincent street. 1870
Bower, F. O., D.Sc., M.A., F.L.S., Regius Professor of Botany in the University of Glasgow, 45 Kersland terrace. 1885
Bowie, Campbell T., 26 Bothwell street. 1870
Boyd, John, Shettleston Iron Works, near Glasgow. 1873
Boyd, Rev. William, LL.D., 8 Windsor terrace, west. 1885
Brand, James, C.E., 172 Buchanan st. 1880
Brodie, John Ewan, M.D., C.M., F.F.P.S.G., 1 Albany place. 1873
Bromhead, Horatio K., I.A., A.R.I.B.A., 245 St. Vincent st. 1870
Brown, Alexander, 190 Bath street. 1887
*Brown, Hugh, 5 St. John's terrace, Hillhead. 1887
Brown, James, 76 St. Vincent st. 1876
Brown, John, 22 Renfield street. 1879
*Brown, John, 11 Somerset place. 1881
Brown, John C., 149 West George street. 1880
Brown, Nicol, F.G.S., 7 Princess road, Brownswood park, South Hornsey, London, N. 1869
Brown, Richard, Strone Colliery Co., 49 W. George street. 1855
Brown, Robert, 19 Jamaica street. 1882
*Brown, Wm. Stevenson, 41 Oswald street. 1886
Brownlee, J., 23 Burnbank gardens. 1860
Brownlie, Archibald, Bank of Scotland, Barrhead. 1880
Brownlie, Jas., Victoria Saw Mills. 1877
Brunton, Rev. Alex., Ardbeg villa, Craigpark, Dennistoun. 1884
*Bryce, Charles C., 141 West George street. 1884
Bryce, David, 129 Buchanan street. 1872
*Bryce, Robert, 82 Oswald street. 1886
Buchan, Thos., 249 Argyle street. 1883
*Buchan, Wm. P., S.E., 21 Renfrew street. 1875
Buchanan, Alex. M., M.A., M.D., Professor of Anatomy in Anderson's College, 98 St. George's rd. 1876
Buchanan, George, A.M., M.D., Professor of Clinical Surgery in the University of Glasgow, 193 Bath street. 1875
Buchanan, George S., 11 Ashton terrace. 1845
Buchanan, William L., 212 St. Vincent street. 1873
*Buchanan, William, 10 Carrington street. 1886
Burnet, John, I.A., 167 St. Vincent street. 1850
Burnet, Lindsay, Assoc. M.I.C.E., St. Kilda, Dowanhill. 1882
Burns, J., M.D., 15 Fitzroy place, Sauchiehall street. 1864
Burns, J. Cleland, 1 Park gardens. 1874

Callajon, Ventura De, 2 Carlton terrace, Kelvinside. 1886
Cameron, Charles, M.D., LL.D., M.P., 104 Union street. 1870
Cameron, H. C., M.D., 203 Bath street. 1873
Cameron, R., 123 St. Vincent st. 1873
*Campbell, Sir A. C., Bart., M.P., of Blythswood, Renfrew. 1885
Campbell, J. A., LL.D., M.P., 137 Ingram street. 1848
*Campbell, James, 137 Ingram st. 1885
Campbell, John D., Merroughsdale cottage, Copeland road, Govan. 1858
Campbell, John MacNaught, Kelvingrove Museum. 1883
*Campbell, Louis, 3 Eton terrace, Hillhead. 1881
Carlile, Thomas, 23 West Nile st. 1851
Carmichael, Neil, M.D., C.M., 29 S. Cumberland street. 1873
Carmichael, Thomas, 11 Kersland terrace. 1879
Carrick, John, I.A., City Architect, 74 Hutcheson street. 1846
Carter, James C., Lecturer on Anatomy, Western Medical School, Hillhead. 1885
Cassels, Robert, 168 St. Vincent st. 1858

Cayzer, Charles W., 109 Hope st. 1886
Chalmers, James, 101 St. Vincent street. 1884
Cherrie, James M., Clutha cottage, Tollcross. 1876
Christie, James, A.M., M.D., F.F.P.S.G., 2 Great Kelvin terrace, Bank street, Hillhead. 1876
115 Christie, John, Turkey-red Works, Alexandria, Dumbartonshire. 1868
Chrystal, W. J., Shawfield Works, Rutherglen. 1882
Church, W. R. M., C.A., 75 St. George's place. 1885
Clapperton, Charles, 16 Lilybank gardens, Hillhead. 1882
Clapperton, John, 5 Sandyford place. 1874
120*Clark, G. W., Dumbreck house. 1877
Clark, Henry E., L.R.C.S. Eng., 24 India street. 1876
Clark, John, Ph.D., F.I.C., F.C.S., 138 Bath street. 1870
Clark, John, 9 Wilton crescent. 1872
*Clark, William, Mile-end. 1876
125 Clavering, Thos., 27 St. Vincent pl. 1856
Cleland, John, M.D., LL.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 1884
Clinkskill, James, 1 Holland place. 1868
Clouston, Peter, 1 Park terrace. 1861
Coats, Joseph, M.D., 31 Lynedoch street. 1873
130*Cochran, Robert, 7 Crown circus, Dowanhill. 1877
Coghill, Wm. C., 263 Argyle street. 1873
Coleman, J. J., F.I.C., F.C.S., F.R.S.E., Ardarrach, Bearsden. 1869
Collins, Sir William, F.R.G.S., 3 Park terrace, East. 1869
Colquhoun, Jas., 158 St. Vincent street. 1876
135 Colville, James, M.A., D.Sc., 15 Newton place. 1885
Combe, William, 257 W. Campbell street. 1877
Connal, Sir Michael, Virginia buildings. 1848
Connell, James, 182 Crookston street. 1870
Connell, Wm., 38 St. Enoch square. 1870
140 Cooke, Stephen, 85 Buccleuch st. 1886
Copeland, Jas., Dundonald road, Kelvinside. 1869
Copland, Wm. R., M. Inst. C.E., 146 West Regent street. 1876
Coubrough, A. Sykes, Blanefield, Strathblane. 1869
Couper, James, Craigforth House, Stirling. 1862
145 Cowan, M'Taggart, C.E., 27 Ashton terrace, Hillhead. 1876
Craig, Alexander T., 264 St. Vincent street. 1884
Craig, John, 94 Paterson street, Kingston. 1885
Craig, T. A., C.A., 139 St. Vincent street. 1886
Crawford, David, Jun., Glengowan Print Works, Caldercruix, by Airdrie. 1873
150 Crawford, Robert, 84 Miller st. 1886
Crawford, W. B., 104 West Regent street. 1872
Crawford, Wm. C., M.A., Lockharton gardens, Slateford, Edinburgh. 1869
Cree, Thomas S., 21 Exchange sq. 1869
Cross, Alexander, 14 Woodlands terrace. 1887
155 Cruikshank, George M., 62 St. Vincent street. 1885
Cunningham, John M., Clydesdale Bank. 1881
Cunningham, J. R., Jun., 15 Windsor circus, Kelvinside. 1881
Curphey, Wm. Salvador, 268 Renfrew street. 1883
Cuthbert, Alexander A., 14 Newton terrace. 1885
160*Cuthbertson, Sir John N., 29 Bath street. 1850

Dansken, A. B., 179 West George street. 1877
*Dansken, John, I.M., 121 West Regent street. 1876
Darling, Geo. E., 178 St. Vincent street. 1870
Davidson, John, 51 Grant street. 1885
165 Day, St. John Vincent, C.E., F.R.S.E., 115 St. Vincent street. 1866
Deas, Jas., C.E., 7 Crown gardens, Dowanhill. 1869
Dempster, John, Cambridge terrace, Albert Road, Pollokshields. 1875
Dennison, William, C.E., 175 Hope street. 1876
Dewar, Duncan, St. Fillans, West Coates, Cambuslang. 1877
170*Dick, George Handasyde, 136 Buchanan street. 1887
Dittmar, W., LL.D., F.R.S., L. & E., Professor of Chemistry, Anderson's College. 1875
*Dixon, A. Dow, 10 Montgomerie crescent, Kelvinside. 1873
Dixon, Edward M., B.Sc., 11 Hopetoun place. 1860
Dobbie, A. B., M.A., University. 1885
175 Donald, John, Dennistoun Public School. 1872
Donald, William J. A., 27 St. Vincent place. 1877

Donald, Alex. W., Bank place, Cambuslang. 1880
Dougall, Franc Gibb, 167 Canning street. 1875
Dougall, John, M.D., C.M., F.F.P.S.G., Lecturer on Materia Medica, Royal Infirmary School of Medicine, 6 Belmar terrace, Pollokshields. 1876
Douglas, Campbell, I.A., 266 St. Vincent street. 1870
Downie, James, North Bank house, Kirkintilloch. 1872
Downie, R. M., 95 Bath street. 1883
Downie, Robert, Jun., Carntyne Dye-works, Parkhead. 1872
Downie, Thomas, Hyde Park Foundry. 1886
Drew, Alex., 175 West George st. 1869
Duncan, Eben., M.D., C.M., F.F.P.S.G., 4 Royal crescent, Crosshill. 1873
Duncan, Robert, Engineer, Partick Foundry. 1875
*Duncan, Walter, 9 Montgomerie crescent. 1881
Dunlop, E. D., 68 St. Vincent st. 1883
*Dunlop, Nathaniel, 1 Montgomerie crescent, Great Western road. 1870
Dunn, Robert Hunter, 4 Belmont crescent. 1878
Dyer, Henry, M.A., C.E., 8 Highburgh terrace, Dowanhill. 1883
Dyer, Rev. John Joseph, 10 Hill street, Springburn. 1885

Eadie, Alexander, 280 Cathcart road. 1885
Easton, Walter, 125 Buchanan st. 1878
Easton, William J., 150 West Regent street. 1876
Edwards, John, Govanhaugh Dye Works. 1883
Elder, James, C.E., 204 St. Vincent street. 1881
Elgar, Francis, LL.D., Admiralty, London. 1884
Erskine, Jas., M.A., M.B., L.F.P.S., 6 Newton street. 1886
*Ewing, Wm., 7 Royal Bank place. 1883

Fairweather, Wallace, C.E., 62 St. Vincent street. 1880
Falconer, Patrick, 33 Hayburn crescent, Partick. 1876
Falconer, Thos., 50 Kelvingrove st. 1880
Farquhar, John, 13 Belhaven terrace. 1872
Fawsitt, Charles A., 4 Maule terrace, Partick. 1879
Fergus, Andrew, M.D., M.R.C.S. Eng., 191 Bath street, *Hon. Vice-President.* 1868
Fergus, Jas., 5 Burnbank gardens. 1880
Ferguson, John, M.A., LL.D., Professor of Chemistry, University of Glasgow. 1869
Ferguson, Peter, 15 Bute gardens, Hillhead. 1866
Ferguson, Thomas, Westmuir st., Parkhead. 1883
Ferguson, William Muir, 116 St. Vincent street. 1883
Fergusson, Alex. A., 48 M'Alpine street. 1847
Fife, William, 52 Glassford street. 1880
Finlay, Joseph, Clairmont, Winton drive, Kelvinside. 1873
Finlay, Robert Gilchrist, Jun., Holmfield, Dalmuir. 1881
Finlayson, James, M.D., 2 Woodside place. 1873
*Fleming, James, 136 Glebe street. 1880
*Fleming, William James, M.D., 155 Bath street. 1876
Foulis, William, C.E., 42 Virginia street. 1870
*Fowler, John, Kelvinbank terrace, Sandyford. 1880
Frame, James, Union Bank of Scotland, 113 King street, Tradeston. 1885
Frame, Thomas, 40 Royal Exchange square 1863
Fraser, Robert, 2 Crown gardens, Dowanhill. 1885
Frazer, Daniel, 127 Buchanan st. 1853
Frew, Alex., C.E., 175 Hope street. 1876
Fullarton, J. H., M.A., B.Sc., Natural History Department, University. 1886
Fyfe, Peter, 1 Montrose street. 1886

Gairdner, Charles, Broom, Newton-Mearns. 1884
Gairdner, C. D., C.A., 115 St. Vincent street. 1886
Gairdner, W. T., M.D., LL.D., Professor of Practice of Medicine in the University of Glasgow, 225 St. Vincent street. 1863
Gale, Jas. M., C.E., Water Office, 23 Miller street. 1856
Galloway, T. Lindsay, C.E., 43 Mair street, Plantation. 1881
Gardner, Daniel, 36 Jamaica street. 1869
*Garroway, John, 58 Buchanan st. 1875
Geddes, Wm., Battlefield, Langside. 1846
Gibb, Peter, 10 Granby terrace. 1883
Gillespie, Edward, Chapel Croft, Cambuslang. 1882
Gillies, Wm., Battlefield, Langside. 1869
Gillies, W. D., 2 Royal Exchange court. 1872
Gilfillan, Wm., 129 St. Vincent st. 1881
Glaister, John, M.B., 4 Grafton place. 1879

Goldie, James, 40 St. Enoch square. 1883
Goodwin, Robert, 58 Renfield st. 1875
245 Gossman, Edwin, 58 West Regent street. 1885
Gourlay, John, C.A., 24 George square. 1874
Gourlay, Robert, Kirklee avenue, Great Western road. 1869
Gow, Leonard, Jun., 19 Waterloo street. 1884
Gow, Robert, Cairndowan, Dowanhill gardens. 1860
250 Graham, David, Jun., 140 Douglas street. 1876
*Graham, William, 195 Bath street. 1885
Grant, Robt., M.A., LL.D., F.R.S., Professor of Astronomy in the University of Glasgow, Observatory, *Hon. Vice-President.* 1860
Gray, James, M.D., 15 Newton terrace. 1863
Gray, James, 2 Balmoral crescent, Crosshill. 1876
255 Greenlees, Alex., M.D., 33 Elmbank street. 1864
Grierson, James, 5 Belhaven cres., Kelvinside. 1880
Grieve, John, M.A., M.D., F.R.S.E., care of W. L. Buchanan, 212 St. Vincent st. 1856
Griffiths, Azariah, Elmbank, Falkirk. 1886
Guild, J. Wyllie, C.A., 17 Park terrace. 1884

260 Haldane, T. Fred., Cartvale Chemical Works, Paisley. 1884
Hamilton, Andrew, 2 Belmar terrace, Pollokshields. 1884
Hamilton, Geo., 149 St. Vincent street. 1871
Hamilton, John, I.A., 212 St. Vincent street. 1885
Hamilton, Patrick, 149 St. Vincent street. 1854
265 Hamilton, David C., 21 Carlton place. 1880
Hannay, Anthony, 25 Exchange square. 1856
Hannay, Jas. B., F.R.S.E., F.C.S., Annfield Chemical Works, Sword street. 1879
Hannay, Maxwell, 104 West George street. 1881
Hart, Arthur, 20 Woodlands terrace. 1883
270 *Harvie, John, Secretary, Clydesdale Bank, 30 St. Vincent place. 1880
*Henderson, A. P., 10 Crown terrace, Dowanhill. 1880
Henderson, George G., B.Sc., Chemical Laboratory, University. 1883
*Henderson, John, Jun., 4 Crown terrace, Dowanhill. 1879
Henderson, Robert, 27 Union st. 1885
275 Henderson, Thos., 47 Union street. 1855
Henderson, Wm., Ennerdale, Winton drive, Kelvinside. 1853
*Henderson, Wm., 15 Cadogan st. 1873
Henry, R. W., 8 Belhaven cres. 1875
Heys, Zechariah J., South Arthurlie, Barrhead. 1870
280 Higginbotham, James S., Springfield court, Queen street. 1874
Higginbotham, Robert Ker, 10 Great Hamilton street. 1885
Higgins, Henry, Jun., 252 West George street. 1878
Hodge, William, 27 Montgomery drive, Kelvinside. 1878
Hoey, David G., 196 St. Vincent street. 1869
285 Hogg, Robert, Inglisby villa, Pollokshields. 1865
Holt, T. G., 25 Wellington street. 1875
Honeyman, John, F.R.I.B.A., 140 Bath street. 1870
Horne, R. R., C.E., 150 Hope st. 1876
Howat, William, 37 Elliot street. 1885
290 Howatt, James, I.M., 146 Buchanan street. 1870
Howatt, William, I.M., 146 Buchanan street. 1870
Hudson, John G., 18 Aytoun road, Pollokshields. 1883
Hunt, Edmund, 87 St. Vincent street. 1856
*Hunt, John, Milton of Campsie. 1881
295 Hunter, James, 156 St. Vincent street. 1874

Inglis, John, 64 Warroch street. 1850

*Jack, William, M.A., LL.D., Professor of Mathematics in the University of Glasgow. 1881
Jamieson, Andrew, F.R.S.E., A.M.I.C.E., M.S.T.E., &c., Principal, College of Science and Arts. 1881
Johnson, James Yate, C.E., 115 St. Vincent street. 1883
300 Johnstone, Jas., Coatbridge street, Port-Dundas. 1866

Kennedy, Hugh, Redclyffe, Partick. 1876
Kennedy, William, St. Margaret's, Newark Drive, Pollokshields. 1882
Ker, Charles, M.A., C.A., 1 Windsor terrace, west. 1885
*Ker, Wm., 1 Windsor ter., west. 1874
305 Kerr, Adam, 175 Trongate. 1887
Kerr, Charles James, Greenfaulds house, Cumbernauld. 1877

Kerr, James Hy., 1 Virginia st. 1872
Kerr, John G., M.A., Garshake, Cambuslang. 1878
Key, William, Tradeston Gas-works. 1877
310 King, James, 57 Hamilton drive, Hillhead. 1848
King, Sir James, LL.D., of Levernholm, 115 Wellington street. 1855
Kirk, Alexander C., 19 Athole gardens, Dowanhill. 1869
Kirk, Robert, M.D., Newton cottage, Partick. 1877
Kirkpatrick, Alexander B., 24 Berkeley terrace. 1885
315 Kirkpatrick, Andrew J., 179 West George street. 1869
Kirkwood, Anderson, LL.D., 7 Melville terrace, Stirling. 1869
Kirsop, John, 98 Argyle street. 1855
Knox, Adam, 47 Crownpoint road. 1881
Knox, John, 129 West George st. 1870
320 Knox, John, 151 Renfrew street. 1883

Laidlaw, John, 35 Hope street. 1885
Laird, George, 10 Ann street, Bridgeton. 1870
Laird, George H., 159 Greenhead street. 1882
Laird, John, Marchmont, Port-Glasgow. 1876
325 Laird, John, Royal Exchange Sale Rooms. 1879
Lamb, Thomas, 220 Parliamentary road. 1870
Lang, William, Jun., F.C.S., Crosspark, Partick. 1865
Latta, James, 8 Miller street. 1869
Latta, John, 138 West George street. 1880
330 Lazenby, Rev. Albert, 2 Regent Park square. 1885
Leitch, Alexander, 60 Rosebank terrace, Grant street. 1886
Lester, William, 2 Doune terrace, N. Woodside. 1884
Lester, W. R., M.A.C.E., 2 Doune terrace, N. Woodside. 1884
Limont, William, Lecturer on Physiology, 7 Melrose street. 1885
335 Lindsay, Archd. M., M.A., 87 West Regent street. 1872
Lindsay, Wm. G., 157 St. Vincent street. 1871
Livingston, Robert, 263B Argyle street. 1879
Lochore, John, 8 Bellahouston ter., Ibrox. 1886
*Long, John Jex, 11 Doune terrace, Kelvinside. 1862
340 Lothian, J. Alexander, M.D., L.R.C.S.E., 6 Newton terrace. 1872
Low, James, 176 St. Vincent st. 1878

M'Alley, Robert, Chemical Works, Falkirk. 1872
M'Andrew, John, 17 Park street, East. 1843
Macarthur, J. G., Glen Ogle, Kilmalcolm. 1874
345 M'Call, J., F.R.C.V.S., Prof. of Veterinary Medicine and Surgery, Veterinary College, 85 Buccleuch street. 1866
Maccall, Samuel, 16 Hillsborough square, Hillhead. 1882
M'Callum, George, Rossbank, Tollcross road, Parkhead. 1850
*M'Clelland, Andrew Simpson, C.A., 4 Crown gardens, Dowanhill. 1884
M'Conville, John, M.D., 27 Newton place. 1870
350 M'Crae, John, 7 Kirklee gardens, Maryhill. 1876
M'Creath, James, M.E., 95 Bath street. 1874
M'Culloch, William, 219 Victoria street, Hillhead. 1872
M'Culloch, Hugh, 231 St. George's road. 1880
Macdonald, Arch. G., 8 Park circus. 1869
355 Macdonald, Thomas, 109 Bath st. 1869
M'Ewen, Wm., Jun., 8 Park quadrant. 1869
M'Farlane, Graham Jas., Elderslie. 1882
Macfarlane, Samuel, Meadowbank, Torrance of Campsie. 1876
M'Farlane, Walter, Printworks, Thornliebank. 1869
360 Macfarlane, Walter, 12 Lynedoch crescent. 1885
M'Gill, J. S., 8 Montgomerie quadrant. 1869
M'Gillivray, James P., 209 West Campbell street. 1883
*M'Gilvray, R. A., 129 West Regent street. 1880
M'Gregor, Duncan, F.R.G.S., 37 Clyde place. 1867
365 M'Gregor, James, 1 East India avenue, London, E.C. 1872
M'Grigor, Alexander B., LL.D., 172 St. Vincent street. 1857
M'Houl, David, Ph.D., Dalquhorn works, Renton. 1883
*M'Ilwraith, James, 4 Westbourne terrace, Kelvinside. 1872
Macindoe, William L., M.A., LL.B., 32 Westbourne gardens. 1885
370 M'Intyre, Peter, 130 Ingram st. 1873
M'Ivor, R. W. Emerson, F.I.C., F.C.S., 67 Great Clyde street. 1886
Mackay, John Yule, M.B., C.M., M.D., 34 Elmbank crescent. 1885
Mackay, John, Jun., 354 Sauchiehall street. 1869

*M'Kenzie, W. D., 43 Howard street. 1875
375 *M'Kenzie, W. J., 197 Dumbarton road. 1879
*M'Kendrick, John G., M.D., C.M., LL.D., F.R.S., F.R.S.E., F.R.C.P.E., Professor of Institutes of Medicine in the University of Glasgow, 45 Westbourne gardens. 1877
Mackinlay, David, 6 Great Western terrace, Hillhead. 1855
Mackinlay, James Murray, 4 Westbourne gardens. 1886
M'Kissack, John, 234 W. George street. 1881
380 M'Lachlan, D., 15 Hill street, Garnethill. 1885
Maclae, A. Crum, 147 St. Vincent street. 1884
MacLean, Walter, 2 Bothwell cir. 1887
M'Laren, Robert, Canal street, Port-Eglinton. 1848
*Maclay, David T., 169 W. George street. 1879
385 Maclean, A. H., 8 Hughenden terrace, Kelvinside. 1870
Maclean, Magnus, M.A., 1 Lilybank place, 1885
MacLehose, James J., M.A., 61 St. Vincent street. 1882
M'Lellan, Walter, 129 Trongate. 1856
Macmillan, Daniel, F.E.I.S., 26 Ashton terrace. 1882
390 M'Nab, John, 69 St. Vincent street. 1881
M'Naughton, Duncan, Bearsden. 1883
Macouat, B. R., 37 Elliot street 1885
Macphail, Donald, M.D., Garturk cottage, Whifflet, Coatbridge. 1877
M'Pherson, George L., 26 Albert road, Crosshill. 1872
395 M'Vail, D. C., M.B., 3 St. James' terrace, Hillhead. 1873
Machell, Thomas, 39 Great Western road. 1886
Main, Robert B., 6 Maxwell ter., Pollokshields. 1885
Mann, John, C.A., 188 St. Vincent street, *Treasurer*. 1856
Mann, John, Jun., M.A., C.A., 188 St. Vincent street. 1885
400 Manwell, James, The Hut, 4 Albert road, Pollokshields. 1876
Marwick, J. D., LL.D., F.R.S.E., Killermont House, Maryhill. 1878
Marks, Samuel, Jeanette villa, Tollcross. 1884
*Mason, Stephen, M.P., 24 Belhaven terrace. 1870
Mathieson, Thomas A., 13 East Campbell street. 1869
405 Mavor, James, 134 St. Vincent street. 1885
Mayer, John, 2 Clarinda terrace, Pollokshields. 1860
Mechan, Arthur, 36 Elliot street. 1876
Mechan, Henry, 36 Elliot street. 1879
Menzies, Thos., Hutchesons' Grammar School, Crown street. 1859
410 Michaelson, M., 5 Woodside place. 1878
Middleton, Robert T., 179 West George street. 1860
Millar, James, 158 Parliamentary road. 1870
Miller, A. Lindsay, 121 W. Regent street. 1878
*Miller, Arch. Russell, The Cairns, Cambuslang. 1884
415 *Miller, George, Winton drive, Kelvinside. 1881
Miller, George, M.D., 1 Ibrox ter., Paisley road. 1885
Miller, John (Messrs. James Black & Co.), 23 Royal Exchange sq. 1874
Miller, Richard, 54 St. Enoch square. 1885
Miller, Thomas, 138 Wellington street. 1882
420 *Miller, Thos. P., Cambuslang Dyeworks. 1864
Miller, W. M., 7 Mansfield place, West Regent street. 1867
Mills, Edmund J., D.Sc., F.R.S., Anderson's College. 1875
Milne, William, M.A., B.Sc., F.R.S.E., High School. 1881
Mirrlees, James B., Redlands, Kelvinside. 1869
425 Mitchell, George A., 67 West Nile street. 1883
Mitchell, Jas. L., 10 Gt. Western terrace. 1878
Mitchell, Robert, 12 Wilson street, Hillhead. 1870
*Moffatt, Alexander, 47 Union st. 1874
Moir, Charles S., 92 Union street. 1884
430 *Monteith, Robert, Greenbank, Dowanhill gardens. 1885
Montgomerie, James, 18 Bishop street, Port-Dundas. 1884
Moore, Alexander, C.A., 209 West George street. 1869
Moore, Alexander George, M.A., B.Sc., 13 Clairmont gardens. 1886
Morgan, John, Springfield house, Bishopbriggs. 1844
435 Morrice, Alexander, Tullymet, Aytoun road, Pollokshields. 1873
Morrice, Jas. A., Tullymet, Aytoun road, Pollokshields. 1883
Morison, William, 10 Franklin ter. 1885
Morrison, Donald, LL.D., 4 Victoria terrace, Dowanhill. 1877

Morrison, James, 98 Sauchiehall street. 1869
440 Morrison, Thomas, M.A., LL.D., 2 Eldon terrace, Partick. 1884
Morton, James, M.D., Professor of Materia Medica in Anderson's College, 199 Bath street. 1868
Mossman, John, 6 Queen's terrace, west. 1870
Motion, James Russell, 38 Cochrane street. 1887
Muir, Alex., 65 Eglinton street. 1883
445 *Muir, Allan, 36 George street. 1881
Muir, James, C.A., 149 West George street. 1887
Muir, John, 6 Park gardens. 1876
Muir, T., M.A., LL.D., F.R.S.E., Beechcroft, Bishopton. 1874
Muir, Wm., Lintmill Bleachworks, Neilston. 1882
450 Muir, William R., 7 Kelvingrove terrace. 1877
*Muirhead, Andrew Erskine, Cart Forge, Crossmyloof. 1873
*Muirhead, Henry, M.D., LL.D., F.F.P.S.G., Bushy Hill, Cambuslang, *President*. 1866
Muirhead, James, 5 Eton terrace, Hillhead. 1887
*Muirhead, Robert F., M.A., B.Sc., 69 West Cumberland street. 1879
455 Munro, Daniel, 22 Burnbank ter. 1867
Munsie, George, 1 St. John's ter., Hillhead. 1871
Munsie, Robert George, 10 Berkeley terrace, west. 1883
Murdoch, Jas. B., Hamilton place, Langside. 1855
Murdoch, Robert, 10 King st., S.S. 1880
460 Murdoch, William, 20 Carlton place. 1879
*Murray, David, 169 West George st. 1876
Murray, A. Erskine, Sheriff-Substitute of Lanarkshire, Sundown, Montgomerie drive. 1881

Napier, Alex., M.D., F.F.P.S.G., 3 Royal terrace, Crosshill 1886
Napier, James, Jun., 10 Carment drive, Shawlands. 1870
465 *Napier, John, 23 Portman square, London. 1849
Neilson, Walter M., Queenshill, Ringford, Kirkcudbrightshire. 1843
Nelson, Alex., 80 Gordon street. 1880
Nelson, D. M., 164 St. Vincent st. 1875
*Newlands, Joseph F., 28 Renfield street. 1883
470 Newman, David, M.D., C.M., Pathologist, Royal Infirmary, 18 Woodside place, W. 1877
Nicol, James, City Chambers, 1872
Nicholson, Alex., Jun., 6 Annfield place, Dennistoun. 1883
Niven, Thos. O., C.E., 131 West Regent street. 1884
Nowery, William, 37 Derby street. 1876

475 Ogilvie, William, 1 Doune terrace. 1881
Osborne, Alex., 5 Oakley terrace, Dennistoun. 1870
Outram, D. E., 16 Grosvenor ter., Hillhead. 1878

Park, James, Millburn Chemical Works. 1877
*Parnie, James, 32 Lynedoch street. 1874
480 Paterson, Jas. A., 27 Apsley place. 1882
*Paterson, Robert, C.A., 28 Renfield street. 1881
Paterson, Robert Baird, 180 Trongate. 1883
Paton, Jas., F.L.S., Corporation Galleries, and Kelvingrove Museum. 1876
Paton, William Grant, 43 Mulgrave street, Princes park, Liverpool. 1883
485 Patterson, T. L., F.C.S., at John Walker & Co.'s, Greenock. 1873
Pearce, William, M.P., 10 Park terrace. 1881
Petrie, Alexander, I.A., 111 Bath street. 1885
Pirie, John, M.D., 26 Elmbank crescent. 1877
*Pirrie, Robert, 9 Buckingham ter. 1875
490 Pollock, Arthur, Dillichip Works, Alexandria. 1879
*Pollock, R., M.B., C.M., F.F.P.& S.G., Laurieston house, Pollokshields. 1883
Poynter, John E., 72 Great Clyde street. 1866
Price, Rees, L.D.S.Eng., 163 Bath street. 1883
*Provan, James, 40 West Nile st. 1868

495 Raalte, Jacques Van, 136 West Regent street. 1884
Ramsay, John, of Kildalton, M.P., 5 Dixon street. 1856
Ramsay, Robert, M.D., L.R.C.S.E., Lochwinnoch. 1881
Rankine, David, C.E., 75 West Nile street. 1875
Rankine, Captain John, 31 Airlie terrace, Pollokshields. 1869
500 Rattray, Rev. Alex., M.A., Parkhead parish, 4 Westercraigs, Dennistoun. 1879
Reid, Andrew, 20 North Albion street. 1875
*Reid, Hugh, 10 Woodside terrace. 1880
Reid, James, 10 Woodside terrace. 1870
Reid, J. G., 9 St. Vincent place. 1874
505 Reid, Thos., M.D., 11 Elmbank st. 1869

Reid, William, M.A., High School. 1881
*Reid, William L., M.D., 7 Royal crescent, west. 1882
Reith, Rev. George, M.A., Free College Church, 37 Lynedoch st. 1876
Rennie, John, 87 Park road. 1886
510 Renton, James Crawford, M.D., L.R.C.P.&S.Ed., 2 Buckingham terrace. 1875
Ritchie, R. Brown, 79 West Regent street. 1883
Ritchie, Wm., Jun., Waltry, Milton of Campsie. 1870
Robertson, Archibald, 25 Queen street. 1863
Robertson, Archibald, 12 Hope st. 1867
515 Robertson, Archibald, Ballancleroch, Lennoxtown. 1884
Robertson, Rev. James, D.D., Professor of Oriental Languages in the University of Glasgow. 1884
Robertson, John, 10 Valeview ter., Langside, *Librarian.* 1860
Robertson, J. M'Gregor, M.A., M.B., Muirhead Demonstrator of Physiology, University. 1881
Robertson, Rev. F. L., D.D., 204 Bath street. 1883
520 Robertson, Robert, 41 So. Cumberland street. 1877
Robertson, Robert A., Nenthorne, 42 Aytoun road, Pollokshields. 1877
Robertson, William, C.E., 123 St. Vincent street. 1869
Robertson, Wm., Wellpark Brewery. 1876
Robson, Hazelton R., 14 Royal crescent, west. 1876
525 Rose, Alexander, 18 Huntly gardens, Dowanhill. 1879
Ross, Henry, 7 Park quadrant. 1876
*Ross, John, 9 Westbourne gardens. 1885
Ross, Zachary M. H., M.A., Glasgow Academy. 1885
Rottenburg, Paul, 21 St. Vincent place. 1872
530 Rowan, David, 22 Woodside place. 1863
Rowan, Frederick J., C.E., 121 West Regent street. 1882
Rowan, W. G., 234 West George street 1881
Rundell, R. Cooper, Underwriters' Room, Royal Exchange. 1877
Russell, James B., B.A., M.D., LL.D., 1 Montrose st., *President.* 1862
535 Russell, Thomas, Cleveden, Kelvinside gardens. 1870

Salmon, W. Forrest, F.R.I.B.A., 197 St. Vincent street. 1870
Sandeman, D., Woodlands, Lenzie. 1870
Schmidt, Alfred, 382 New City road. 1881
Scott, Alex., 2 Lawrence place, Dowanhill, *Vice-President.* 1871
540 Scott, Arthur T., M.A., 6 Wilton crescent. 1882
*Scott, D. M'Laren, Carberry villa, Tollcross. 1881
Scott, Robt., I.M., 115 Wellington street. 1884
Seligmann, Hermann L., 135 Buchanan street. 1850
Sellars, Jas., I.A., 266 St. Vincent street. 1873
545 Shaw, John M., 14 Union street. 1880
Sheriff, John, 156 St. Vincent st. 1876
Shirreffs, W., 249 W. George street. 1884
Sim, William, 3 Royal crescent. 1862
Simons, Michael, 206 Bath street. 1880
550 Simpson, P. A., M.A. Cantab., M.D., Regius Professor of Forensic Medicine, University, 1 Blythswood sq. 1881
Sinclair, Alexander, Ajmere lodge, Langside. 1883
Sinclair, D., National Telephone Co., Limited, 8a Royal Exchange buildings. 1883
Sloan, Samuel, M.D., 1 Newton terrace. 1877
Smart, William, M.A., Nunholm, Dowanhill. 1886
555 Smellie, George, I.M., 167 St. Vincent street. 1880
*Smellie, Thos. D., 209 St. Vincent street. 1871
Smillie, R. D., M.S.T.E. and E., Messrs. Wm. Denny & Brothers, Dumbarton. 1883
Smith, Francis, 45 Gordon street. 1875
Smith, Geo., Sun Foundry, Alloa. 1870
560 Smith, Harry J., Ph.D., Coltness Iron-works, Newmains. 1877
Smith, Hugh C., 55 Bath street. 1861
Smith, James, 20 Park terrace. 1881
*Smith, J. Guthrie, 54 West Nile street. 1875
*Smith, Robert B., Bonnybridge, Stirlingshire. 1884
565 Smith, W. R. W., 6 S. Hanover street. 1868
Snodgrass, James, F.C.S., Pumpherston Oil Works, Mid Calder. 1877
Somerville, David, 35 King street, S.S. 1885
Sorley, Robert, 3 Buchanan st. 1878
Spens, John A., 169 W. George street. 1879
570 Spiers, John, 43 Great Western road, Hillhead. 1885
Stanford, Edward C. C., F.C.S., Glenwood, Dalmuir, Dumbartonshire. 1864
Steel, James, 46 Grafton street. 1870
*Stephen, John, Domira, Partick. 1880

Stephen, Robt. R., Adelphi Biscuit Factory. 1867
575 *Steven, Hugh, Westmount, Montgomerie drive. 1869
Steven, John, 32 Elliot street. 1875
Stevenson, Allan, 42 New Market street, Ayr. 1886
*Stevenson, Jas., 23 West Nile street. 1870
Stevenson, John, C.E., 95 Bath st. 1885
580 Stevenson, William, Tower Bank, Lenzie. 1870
Stewart, Andrew, Jordanhill house. 1887
Stewart, David, 3 Clifton place. 1856
Stewart, Henry, City Saw Mills. 1876
Stewart, James, 41 Oswald street. 1887
585 Stewart, James Reid, 30 Oswald street. 1845
Stewart, John, Western Saw Mills. 1877
Stuart, J. Watson, 88 St. Vincent street. 1881
Stirton, James, M.D., F.L.S., 5 Newton terrace. 1876
Stobo, Thomas, 12 Sardinia terrace, Hillhead. 1884
590 Stoddart, James Edward, 60 Robertson street. 1872
Storer, David, 5 Billiter Avenue, London, E.C. 1869
Storer, James, 48 French street, Bridgeton. 1875
Strain, John, C.E., 154 West George street. 1876
Sturrock, David, I.A., 95 Bath street. 1881
595 *Sutherland, David, Great Western Hotel, Oban. 1880
*Sutherland, John, Great Western Hotel, Oban. 1880
Sutherland, J. R., 5 Westercraigs, Dennistoun. 1884
Sutherland, Thos., 24 North St. Mungo street. 1886
Swanston, John, 47 Melville street, Pollokshields. 1872

600 Tatlock, John, F.I.C., 100 Sauchiehall street. 1875
Tatlock, Robt. R., F.R.S.E., F.I.C., F.C.S., 138 Bath street. 1868
Taylor, Benjamin, 10 Derby cres., Kelvinside. 1872
Teacher, Adam, 14 St. Enoch square. 1868
Tennant, Sir Charles, Bart., 217 West George street. 1868
605 Tennant, Gavin P., M.D., 159 Bath street. 1875
Terrace, David, Dawsholm Gasworks, Maryhill. 1883
Thomson, David, I.A., F.R.I.B.A., 116 St. Vincent street. 1869
Thomson, George C., 39 Kersland terrace. 1883
Thomson, Gilbert, M.A., C.E., 75 Bath street. 1885
610 Thomson, Graham Hardie, 10 Doune terrace, North Woodside. 1869
*Thomson, James, F.R.I.B.A., 88 Bath street. 1886
Thomson, James, F.G.S., 3 Abbotsford place. 1863
Thomson, Jas., LL.D., F.R.S., C.E., Professor of Engineering in the University of Glasgow, 2 Florentine Gardens, Hillhead. 1874
Thomson, James R., Clydebank, Dumbartonshire. 1863
615 Thomson, Jonathan, 136 W. George street. 1869
Thomson, Sir William, LL.D., D.C.L., F.R.S., L. & E., Professor of Natural Philosophy, University of Glasgow, *Hon. Vice-President.* 1846
Townsend, Joseph, 19 Crawford st., Port-Dundas. 1856
*Tullis, James Thomson, Anchorage, Burnside, Rutherglen. 1883
Turnbull, John, 37 West George st. 1843
620 *Turnbull, John, jun., M.I.M.E., 255 Bath street. 1883
Turner, George A., M.D., 1 Clifton place, Sauchiehall street. 1883
Turner, William, 33 Renfield st. 1875

Underwood, Francis H., 107 West Regent street. 1886
Ure, John, Crown Mills, 68 Washington street. 1856
625 Urie, John, 83 Jamaica street. 1876

Verel, Wm. A., The Linn, Cathcart. 1883

Walker, Adam, 35 Elmbank cres. 1880
*Walker, Archibald, B.A. (Oxon.), F.C.S., 8 Crown ter., Dowanhill. 1885
Walker, James A., 112 St. Vincent street. 1884
630 Walker, Malcolm M'N., F.R.A.S., 45 Clyde place. 1853
Wallace, Abraham, M.D., 4 Newton place. 1877
*Wallace, Hugh, Mansefield, Kilmalcolm. 1879
Wallace, Wm., Ph.D., F.R.S.E., F.I.C., F.C.S., 138 Bath street, *Hon. Vice-President.* 1851
Wardlaw, Johnston, 83 Taylor st. 1884
635 Watson, Archibald, 29 Elmbank crescent. 1881
Watson, James, Cluniter, Innellan. 1873
Watson, John, 205 West George street. 1886

Watson, Joseph, 225 West George street. 1882
*Watson, Thomas Lennox, I.A., 108 W. Regent street. 1876
640 *Watson, William Renny, 16 Woodlands terrace. 1870
Welsh, Thos. M., 51 St. Vincent crescent. 1883
Wenley, James A., Bank of Scotland, Edinburgh. 1870
Westlands, Robert, 99 Mitchell street. 1869
White, John, Scotstoun mills, Partick. 1875
645 Whitelaw, Alex., 87 Sydney st. 1855
*Whitson, Jas., M.D., F.F.P.& S.G., 13 Somerset place. 1882
Whytlaw, Robert A., 1 Windsor quadrant, Kelvinside. 1885
Whytlaw, R. A., Jun., 1 Windsor quadrant, Kelvinside. 1884
Widmer, Justus, 21 Athole gardens. 1887
650 Williamson, John, 65 West Regent street. 1881
Wilson, Alex., Hydepark Foundry, 54 Finnieston street. 1874
Wilson, Charles, 4 Craigpark, Dennistoun. 1875
Wilson, Daniel, 124 Bothwell st. 1872
Wilson, David, Carbeth, by Killearn. 1850
655 Wilson, John, 11 Woodside place. 1873
Wilson, Peter M'Gregor, Rosevale, Bearsden. 1877
Wilson, William, Virginia buildings. 1881
Wilson, W. H., 45 Hope street. 1881
Wingate, Arthur, 6 Kelvin drive. 1882
660 *Wingate, John B., 7 Crown terrace, Dowanhill. 1881
Wingate, P., 14 Westbourne ter. 1872
Wingate, Walter E., 4 Bowmont terrace. 1880
Wood, James, M.A., Glasgow Academy. 1885
Wood, James, 40 St. Enoch square. 1886
665 Wood, J. Muir, 42 Buchanan st. 1850
Wood, Wm. Copland, Turkey-red Works, Alexandria. 1883
Woodburn, J. Cowan, M.D., 197 Bath street. 1869
Woodburn, W. S., L.D.S., Lecturer on Mechanical Dentistry, Anderson's College, 17 Carlton place. 1881
Wyper, James, 83 Queen Margaret crescent, Hamilton drive. 1878

670 Yellowlees, D., M.D., Medical Superintendent, Gartnavel. 1881
Young, George Christie, City Saw Mills, Port-Dundas. 1884
Young, John, 22 Belhaven terrace, Kelvinside. 1885
Young, John, 234 Parliamentary road. 1881
Young, R. Bruce, M.A., M.B.C.M., University. 1885
675 Young, Robert, 25 St. Vincent crescent. 1875
*Young, Thos. Graham, Westfield, West Calder. 1880
Younger, George, 166 Ingram st. 1847

Zinkeisen, Victor, 30 Cochrane st. 1881

THE PHILOSOPHICAL SOCIETY OF GLASGOW.

INVENTORY of all Property (except the Library) possessed by the Society—made by the Treasurer in compliance with Article XI. of the Articles of Association, and presented to the Annual Meeting on 17th November, 1886.

I.—ITEMS, THE EXCLUSIVE PROPERTY OF THE SOCIETY.

All as detailed in Inventory of 1884, printed in *Proceedings* for 1884-85, Vol. XVI., pp. 405-6, and in that of 1885, printed in Vol. XVII., p. 466, with the following additions:—

READING ROOM.

Stained and varnished Book Rack for Geographical Publications.

II.—ITEMS, THE PROPERTY OF THE SOCIETY JOINTLY WITH THE "INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND."

All as detailed in Inventory of 1884, printed in the *Proceedings* for 1884-85, Vol. XVI., pp. 406-7, and in that of 1885, printed in Vol. XVII., p. 466, with the following additions, viz.:—

LIBRARY.

Frictional Electric Lighter, 17/6, on 5/11/85.

UPPER HALL.

White enamelled Sink, 24 in., with piping, plug, socket, and chain, and wooden stool for same.

Bookboards of seven seats.

JNO. MANN, *Treasurer*.

INDEX.

Abbe's apochromatic micro-objectives and compensating eye-pieces, Adolph Schulze on, 28; apochromatic lenses, advantages of, 35; compensating eye-pieces, 36; apochromatics, new table of, 38.
Aberration of lenses, chromatic and spherical, 30.
Aboriginal Australian, as he was, Arthur Kay on, 146.
Account of treasurer, 406; of Graham Medal and Lecture Fund, 408.
Adam Smith's teaching, 137.
Alexander, Peter, on approximate formulæ for the motion of projectiles, 237; on how to use the polariscope in the practical determination of internal stress and strain, 242.
Allan Glen School, 78.
Alto-Relievo models, use of, in study of history, 116; effectiveness of, 111; for the blind, 116; for the "standards," 113; list of, shown, 117; as true interpreters of the map, 115.
Analysis of ash of animals after cremation, 276.
Anastomotic chains between subclavian and carotid arteries, 311.
Anderson's College, 78.
Anderson, John, on introduction of sea-water into Glasgow, 357.
Andrews' classical work, 124.
Amphisia multiseta, description of, 54.
Amusements amongst Motu-motu tribe, 68.
Architectural Section, Report of, 397; office-bearers of, 398 and 434.
Arterial system of vertebrates homologically considered, Dr. John Yule Mackay on, 302.
Arteries modified in adult vertebrates, 304; of parietal circles, 309; of vertebrated animals of two groups, 302; of visceral circles, 307; of hooded seal, 315.
Atom and molecule, use of terms, by Graham, 122.
Atoms as physical entities, Clerk-Maxwell on, 130.
Auditors, appointment of, 405.
Australian race, origin of, 152.
Automatic electrical lighting of trains, Thomas P. Carswell on, 391.
Average quality of gas used in England and Ireland, 99.

Barus and Strouhal's papers on the electric and magnetic properties of the iron carburets, 42.
Basket coffins, 265.
Beccari on myrmekophilous plants, 323.
Belgium, technical schools in, 77.
Bell's steamer *Comet*, 6.
Biological problems to be solved, 331.
Biological Section, report of, 399; office-bearers of, 435.
Biological teaching in Germany and in this country, J. H. Fullarton on, 327.

"Birds of Ayrshire and Wigtownshire," by Robt. Gray, 280.
"Birds of the basin of the Forth," 282.
Birmingham School of Art, 80.
Bishop Ulfilas' version of the gospels, discovery of, by Arnold Mercator, 207.
Bower, Prof. F. O., on morphological peculiarity of *Cordyline Australis*, 317; on *Humboldtia laurifolia* as a myrmekophilous plant, 320.
Branch arteries connecting ventral and dorsal trunks, 303.
Bray's burners, tests of, 90; gas testing with, by William Key, 93.
British Association conference of delegates, report on, by Dr. Henry Muirhead, 70.
Brown, William, on preliminary experiments on the effects of percussion in changing the magnetic moments of steel magnets, 41.
Bucharest ring, 211.
Burial customs in Australia, 158.
Burial of the poor described, 261.
Burials Act of 1855, 258.
Bursting of leaden service pipes by water and frost, notes on, by George C. Thomson, 102.
Bursts of lead pipes, how produced by water pressure and frost, 107.

Cairnes, Professor, "Political Economy," 136; harmony of his teaching with that of Adam Smith, 137.
Calf lymph violent in action, 372.
Cameron, Dr. Chas., M.P., on cremation and mineral poisoning, 275.
Canada and the States, technical schools in, 77.

Carmichael, Dr. Neil, on an experimental research on the cultivation of vaccine lymph, 369; statement of experiments with vaccine lymph, 374; outcome of investigation summarised, 387.
Carriage, cheaper rates of, 141.
Carswell, Thomas P., on automatic electrical lighting of trains, 391.
Carving and drawing, taste for, among aboriginal Australians, 162.
Cemetery companies, private, 259.
Certain modern developments of Graham's ideas concerning the constitution of matter, by Professor T. E. Thorpe, 118.
Chalmers, Rev. James, on manners and customs of some of the tribes of New Guinea, 57.
Chemical combination, Graham's conception of, 123.
Chemical Section, report of, 401; office-bearers of, 434.
Chief works relating to steam engine, catalogue of, 25, 26, 27.
Chromatic and spherical aberration of lenses, 30.
Circumcision, rites of, in some Australian tribes, 156.
City of London Guilds and technical education, 73.
Classical philology in the English Universities, 234.
Clerk-Maxwell on atoms as physical entities, 130.
Close time for birds, 281.
Clyde sea-area, its boundary line and extent, 335.
Coal gas: and the coal question in its bearings on the illuminating power of gas, William Key on, 87.
Coal gas in cooking, economy of, 87.
Coal supply question, 92.
Coincidences in Aryan and Australian languages, 150.
Coleman, J. J., election of, as Vice-President of Society, 413; as Governor of Glasgow and West of Scotland Technical College, 419; on liquid diffusion, 196.
College of Science and Arts, 78.
Colville, Dr. Jas., on Gothic version of the Gospels by Bishop Ulfilas, and its value in the study of language, 207.
Coming-of-age ceremonies in Australia, 154.
Commission on trade depression, definition of phrase, 135; evidence of specialists, 135; main report on, 135; separate report on, 135.
Committees of Council, 433.
Common passages and stairs, ownership of, 188.
Comparative anatomy of external carotid artery, 305.
Compensating eye-pieces, three kinds of, 37.
Compressibility of water, 103.
Configuration of Clyde sea-area, 334.
Congo, past and present of the, Sir Francis de Winton on, 422.
Constant-standard instruments for measuring electrical currents, 255.
Contamination of pure vaccine lymph, how prevented, 380.
Continuous fall of prices, 140.
Cooke, Stephen, on the action of electric sparks on mixtures of nitric oxide with hydrogen and other inflammable gases, 294; on the decomposition of nitric oxide in contact with water and alkaline solutions, 299; on the reducing action of hydrogen in presence of platinum, 284.
Cordyline Australis, morphological peculiarity of, by Professor Bower, 317.
Cremating furnace proposed and described, 278.
Cremation, objections to practice of, considered, 274; practice of, in Scotland, 269; in other countries, 269; project for revival of, 272; societies, 272.
Crematory, proposed institution of, in Glasgow, 273.
Crookes on elemental form of matter, 129.

Dalton, John, life of, 125.
Death ceremonies in New Guinea, 65.
Definite integrals, note on a class of, by Geo. A. Gibson, 167.
Definition of national wealth, by Professor Fawcett, 138.
Development of the marine engine, Henry Dyer, on, 1.
Dieyerie tribe tradition, 148.
Diffraction theory of formation of microscopical image, 31.
Diffusibility, relation of, to atomic or molecular volume, 202.
Diffusion, liquid, J. J. Coleman, on, 196.
Diffusion-jar, 197.
Dilatancy, demonstration on, by R. F. Muirhead, 400 and 418.
Disposal of the dead, reform of our present methods of, by Dr. Eben. Duncan, 257.
Domestic life in Australia, simplicity of, 159.
Downward-growing shoots of *Cordyline Australis* described, 318.
Dr. Cameron's Disposal of Dead Regulation Bill, 274.
Dr. Mill's methods of working, 336; inquiry, result of, 341.

Drawing, design, and modelling in Glasgow Board Schools, 79.
Duncan, Dr. Eben., on reform of our present methods of disposal of the dead: earth-to-earth burial *versus* cremation, 257.
Dundas, *Charlotte*, paddle-wheel steamer, 6.
Dyeing school, proposed, 85.
Dyer, Henry, on the development of the marine engine, 1.
Dynamical theory of steam-engine, 9.

Eassie on cremation of the dead, 273.
Economic Science Section, inaugural address to, 133; time favourable for opening of, 134; report of, 402; office-bearers of, 402; formation of, 419; interim report on, 421; constitution of, 423.
Economical use of gas for lighting, 89.
Economy of coal gas in cooking, 87.
Effect of severe winter weather on rich gas, 99.
Electric sparks, action of, on gaseous mixtures, Stephen Cooke on, 294.
Electrical and magnetic properties of the iron carburets, Barus and Strouhal's paper on, 42.
Electrical lighting of trains, 391.
Electrical measuring instruments, double chain of, by Sir William Thomson, 249; fundamental requisite of, 249.
Electro-dynamic balance, 256.
Electrostatic voltmeter, 250.
Elemental forms of matter, Crookes and Lockyer on, 129.
Embedding and cutting microscopical sections in paraffin, A. B. Kelly on, 419.
Engine, marine, development of, 1.
Engine, steam, Hugo Reid's paper on invention of, 3; inverted, beam or side lever, 7.
Engineers, Institution of, 2.
Engines of steamers *Aberdeen* and *Propontis*, 12.
Engines, triple expansion, 11.
English and lowland Scotch, relation of, to Gothic, 213.
Erratic blocks, 72.
Essential unity of matter, idea of, 126.
Exchanges with other societies, &c., list of, 441.
Express grant and implied grant in constituting servitudes, 173; examples of, 174.
Experiments, preliminary, on the effects of percussion in changing the magnetic moments of steel magnets, by William Brown, 41.
Experimental research on the artificial cultivation of vaccine lymph, by Dr. Neil Carmichael, 369.
External carotid artery, comparative anatomy of, 305.

Fall in prices, the chief factor in trade depression, 144.
Fawcett's definition of national wealth, 138.
Ferguson, Archibald, on some minor rights of land ownership, 170.
First two beings, Western Australian legend of, 149.
Foreign tariffs and bounties, 140; competition in trade, 140.
Formation of microscopical image, diffraction theory of, 31.
Foulis' gas-fire, John Mayer on, 365.
France, technical schools in, 76.
Fullarton, J. H., on biological teaching in Germany and in this country, 327.
Fulton's steamer *Clermont*, 6.

Gairdner, Charles, on an examination of the report of the Royal Commission on depression of trade, 133.
Galvanometers, 253.
Gaseous molecule, 122.
Gas for lighting, economical use of, 89.
Gas testing with Bray's burners, 93.
Genus *Humboldtia*, where natives, 321.
Geographical alto-relievo models and their place in education, by William Martin, 108.
Geographical and Ethnological Section, report of, 398; office-bearers of, 398, 435.
Geographical teaching in private academies and board schools, 108; curriculum for the "standards," 109.
German universities, recent growth of, 328.
Germs of putrefaction, 268.
Gibson, George A., note on a class of definite integrals, 167.
Gladstone and Tribe on occluded hydrogen, 284.
Glasgow and West of Scotland Technical College, 79.
Glasgow City and District Railway—train-lighting arrangements described, 392.
Glasgow city burial-grounds, report on, 260.
Glasgow Corporation Water-works: rules as to lead pipes, 104.
Glasgow swimming ponds, 363.
Glasgow Underground Railway, three electrical circuits in, 394; how formed, 394.
Glasgow Weaving College, progress of technical education with special reference to, by David Sandeman, 73.

Glasgow Weaving School, hours of instruction in, 83; number of pupils in, 83; work done in, 83.
Glass, lines of stress in, illustrated, 245.
Gorini and Siemens' crematories, 273.
Gothic grammar, 229; the verb, 229; the passive verbal form, 231; demonstratives and relatives, 232.
Gothic version of the Gospels, by Bishop Ulfilas, and its value in the study of language, Dr. James Colville on, 207.
Gothic words dealing with man and his personal environment, 219; with man's natural surroundings, 221; with man and his activities, 223.
Goths, brief account of, 210.
Graham and Dalton compared, 124.
Graham lecture, by Professor Thorpe, 118.
Graham Medal and Lecture Fund account, 408.
Graham, Professor of Chemistry in Andersonian Institution, 118; his first paper, 196; his position as an atomist, 120.
Gray, Robert (the late), J. B. Murdoch on, 279; birthplace of, 279; teller in City of Glasgow Bank, 279; life in Edinburgh, 282.
Great Spirit, knowledge of, amongst New Guinea tribes, 65.
Grimm's law, 212.
Grocers' Company, prize of £1000, 373.

Haden, Francis—letters to the *Times* on burial of the dead, 266.
Heat-engine and steam-engine defined, 3.
Heating by gas fires, 88.
Heat-regeneration in the "Foulis" gas-fire, 366.
High grades of steam expansion in marine engines, 14.
High potential circuits, 253.
Historical grammar, 228.
Hospital gangrene and pyæmia, 264.
Hugo Reid's paper on invention of steam-engine, reference to, 3.
Hull's patent engine for ship propulsion, 5.
Humboldtia laurifolia, Prof. Bower on, 320.
Hydrogen and platinum foil, action of, on nitric acid, 285; on nitrates, 287; on chlorine, bromine, and iodine, 288; on concentrated sulphuric acid, 289; on permanganates, 289; on other classes of salts, 290; on nitric oxide, 291.

Illuminating power of gas in English towns, 92.
Indo-European family of tongues, 212.
Infanticide among native Australians, 157.
Institution of Engineers, 2.
Intramural interment and Town Council of Glasgow, 260.
Introduction of sea-water into Glasgow, John Anderson on, 357; estimated cost of proposed scheme, 358.
Introduction to Gothic, by Mr. Douse, 234.

Jar diffusion, 197; results, table of, 198.
"Johnny Gibb o' Gushetneuk," 219, 228, 235.
Justice Stephen on legality of cremation, 274.

Kay, Arthur, on the aboriginal Australian, as he was, 146.
Keddie, William, early history of Philosophical Society, 1.
Key, William, on coal gas: and the coal question in its bearings on the illuminating power of gas, 87.
Kidney fat, curious Australian superstition regarding, 149.
Kirk, A. C., and engines of steamer *Aberdeen*, 12; and steamer *Propontis*, 11.
Koitapu tribe, 57.

Land ownership, some minor rights of, by Archibald Ferguson, 170.
Langley, Prof. S. P., reference to, 253.
Latham, Baldwin, reference to, 264.
Lead, different qualities of, 103; impurities in, 103; properties affected by impurities in, 103; pipe in Royalty Theatre, 104.
Leaden service pipes, burst specimens, 102.
Legislation affecting employment of labour, 141.
Legislative enactments in restraint of labour, 142.
Library, additions to, 437.
Library Committee, report by, 412.
Life of John Dalton, 125.
Light vibrations explained, 243.
Liquid diffusion, J. J. Coleman on, 196.
List of members, 446.
Lister's prediction as to infectious diseases, 372.
Lockyer on elemental forms of matter, 129.
Loss to Glasgow public by using 26-candle gas, 95.
Lymph of two kinds, 372.

Macadam, Dr. Stevenson, on gas testing, 90.
Mackay, Dr. John Yule, on the arterial system of vertebrates homologically considered, 302.

Magnetic moments in absolute measure, investigations on, by T. Gray, 41.
Magnetising operations described by William Brown, 44; magnetic moment of magnets, loss of, 46.
Magnets of "silver steel," 43; tempering of, 43.
Magnus, Sir Philip, and technical education, 81.
Manganese, its effects on magnetic retentiveness and magnetic susceptibility, 43.
Mann, John, re-election of, as Treasurer, 413.
Manners and customs of some of the tribes of New Guinea, Rev. James Chalmers on, 57.
Marine biological stations, 331.
Marine engine, development of, 1; definition of, 3; classes of, 7; oscillating, 8; high grades of steam expansion in, 14; improvements on, by Elder, Randolph, and J. M. Rowan, 10; piston speed in, 24; results of improvements in, 19; steam jacket for cylinders of, 16; surface condensation in, 18.
Marriage among aboriginal Australians, 156.
Marriage customs in the Motu tribe, 63.
Marshall's statistics of mercantile marine, 21.
Martin, William, on geographical alto-relievo models and their place in education, 108.
Mathematical and Physical Section, report of, 399; office-bearers of, 399 and 436.
Mayer, John, election of, as Secretary, 414; on Foulis' gas-fire: a new departure in using gaseous fuel for domestic purposes, 365.
M'Kendrick, Professor, description of new rocking microtome by, 414.
Measurement of high temperature by air thermometer, J. T. Bottomley on, 428.
Meldola, Prof., secretary British Association conference of delegates, 72.
Members of Society, list of, 446.
Meteorological and phenological observations, 72.
Micrococci in vaccine lymph, 370.
Micro-objective defined, 29; numerical apertures of, 32.
Microtome, new rocking, described by Dr. M'Kendrick, 414.
Mill, Dr. H. R., on physical condition of water in the Clyde sea-area, 332.
Milne, William, on a new tentaculiferous protozoon and other infusoria, with notes on reproduction and the function of the contractile vesicle, 48.
Minutes of Session, 404.
Molecular measurements, Sir William Thomson on, 132.
Monthly variation of temperature in Clyde sea-area, 348.
Motu husband and wife, 63.
Motu tribe and village, 57.
Motuan children, 64.
Muirhead, Dr. Henry, on conference of delegates at Birmingham meeting of British Association, 70.
Murdoch, J. B., on the late Robert Gray, 279.
Mutual gables, 180; floor ceilings, 188.
Myrmecodia, study of, by Treub, 321.
Myrmekophilous plants of Malayan and Papuan Archipelago, 320.
Myths of aboriginal Australian, 147.

Napier, David, and side-lever engine, 8.
National Vaccine Establishment circular, quotation from, 385.
Native ovens, or mirnyongs, in Australia, 165.
Natural History Society of Glasgow, origin of, 280; Robert Gray's secretaryship of, 280.
Newcomen's engine, 4.
New Guinea, manners and customs of some of the tribes of, by Rev. James Chalmers, 57.
New honorary members—election of Professor G. G. Stokes, 429; Professor Donders, 429; letters from, 430.
New ordinary members—
Andrews, D. J. F., 421.
Blackie, Walter Wilfrid, 405.
Brown, Alexander, 421.
Brown, Hugh, 424.
Brown, Wm. Stevenson, 418.
Bryce, Robert, 416.
Buchanan, William, 405.
Cayzer, Charles W., 415.
Cooke, Stephen, 405.
Craig, T. A., 416.
Crawford, Robert, 405.
Cross, Alexander, 424.
De Callajon, Ventura, 405.
Dick, George Handasyde, 424.
Downie, Thomas, 418.
Erskine, Dr. James, 416.
Fullarton, J. H., 415.
Fyfe, Peter, 416.
Gairdner, C. D., 405.
Griffiths, Azariah, 416.
Ker, Adam, 424.
Leitch, Alexander, 415.
Lochore, John, 416.
Machell, Thomas, 418.
MacIvor, R. W. Emerson, 416.
MacKinlay, James Murray, 405.
MacLean, Walter, 420.
Moir, Charles S., 415.

New ordinary members (*continued*)—
Moore, Alex. George, 418.
Motion, James Russell, 420.
Muir, James, 424.
Muirhead, James, 424.
Smart, William, 405.
Stewart, Andrew, 424.
Stewart, James, 424.
Thomson, James, 405.
Underwood, Francis H., 418.
Watson, John, 415.
Widmer, Justus, 427.
Wood, James, 416.
Nitric oxide, decomposition of, in contact with water and alkaline solutions, Stephen Cooke on, 299.
Normal vaccine vesicles produced artificially, 383.

Observations, meteorological and phenological, 72.
Office-bearers for 1886-87, 434; of Sections, list of, 434.
Ophrydium sessile, description of, 53.
Optical glasses, manufacture of, at Jena, 34.
Ordinary coal fire a wasteful one, 89.
Origin of the Philosophical Society, 1.
Oscillating marine engine, 8.
Otto gas engine, 87.
Over-production in trade, 139.
Oxytricha tricornis, description of, 52.

Papin's steam-engine, 4.
Parochial law of Scotland, Duncan's treatise on, 259.
Partition walls, ownership of, 188.
Pasteur, M., on chicken cholera, 385; on spread of splenic fever, 268; quoted in regard to virus of fowl cholera, 384.
Peradeniya Gardens, 317.
Periodicals, list of, 444.
Philology, true progress in, 213.
Philosophical Society, origin of, 1.
Physical condition of the water in the Clyde sea-area, Dr. H. R. Mill on, 332.
Physical states of matter, continuity of, 123.
Piston speed in marine engine, 24.
Pit burial, 261.
Plants giving shelter to ants, 320.
Platinum black, its chemical activity, 284; its action on mixture of electrolytic gases, 285.
Playfair, Sir Lyon, on secret poisonings, 274.
Polariscope, use of, in determining internal stress and strain, Peter Alexander on, 242; explained, 243.
"Polarization of Light," Spottiswoode's, quotation from, 242.
Polarizer and analyzer, action of, 244.
Polygamy amongst New Guinea tribes, 64.
Prescription, doctrine of, 178.
Proceedings of the Society, proposed general index to, 416.
Projectiles, approximate formulæ for motion of, by Peter Alexander, 237.
Property, great shrinkage in value of, 143.
Propontis, steamer, reference to, 11.
Proposed course of sea-water conduit from Saltcoats, 358.
Proposed regulations for burial grounds, 265.
Prout's law, 127.
Public Health (Scotland) Act, 258.

Quadrant electrometer, 250.

Reducing action of hydrogen in presence of platinum, Stephen Cooke on, 284.
Regenerator gas-fire, illustrated, 367.
Rental of dwelling-houses above £20 in Glasgow and suburbs, 363-4.
Report by Council, 409.
Report by Library Committee, 412.
Report from the conference of delegates at Birmingham Meeting of British Association, by Dr. Henry Muirhead, 70.
Report of the Royal Commission on depression of trade, an examination of, by Charles Gairdner, 133; inconclusive and disappointing, 145.
Reports of Sections, 397.
Reprint of Graham's papers, Dr. Angus Smith's preface to, 119.
Reproduction in the *Strombidinopsis proboscidifer*, 52.
Results of improvements in marine engines, 19.
Robertson, David, on animal life in Clyde sea-area, 356.
Robertson, John, re-election of, as Librarian, 413.
Runes, a relic of Teutonic antiquity, 214.
Runic alphabet, 214.
Russell, Dr. J. B., election of, as President, 413.

Salts and solutions, Professor Graham on, 121.
Salutation forms amongst New Guinea tribes, 64.
Sandeman, David, on progress of technical education, with special reference to Glasgow Weaving College, 73.
Sanitary and Social Economy Section, report of, 401; office-bearers of, 401 and 435.

Schulze, Adolf, on Abbe's apochromatic micro-objectives and compensating eye-pieces, 28.
Science and Art Department and technical education, 78.
Scotland in alto-relievo, 113.
Scottish Burial Reform Association proposed, 277.
Sea-coasts erosion, 72.
Sea-water bathing, value of, 361.
Search oculars and working oculars, table of, 39.
Secondary or branch arteries of vertebrates, 306.
Sections, reports of, 397.
Servitudes are not rights of ownership, 170; of light and air, 171; positive and negative, 172.
Shell mounds in Australia, 165.
Shining stones or crystals held in great veneration in South-Western Australia, 153.
Ship propulsion, Miller, Taylor, and Symington's experiments in, 6.
Shroud burials, 265.
Silurian fossils of the Girvan district, Royal Society's grant for publication of, 282.
"Silver steel," magnets of, 43.
Sir Francis de Winton on the Congo: its past and present, 422.
Spherical and chromatic corrections for lenses, 34.
Splenic fever, M. Pasteur, on spread of, 268.
Steam-engine, catalogue of chief works relating to, 25, 26, 27; dynamical theory of, 9.
Steam jacket for cylinders of marine engines, 16.
Steam yacht *Medusa*, her equipments, 337.
Steel magnets, preliminary experiments on the effects of percussion in changing the magnetic moments of, by William Brown, 41.
Stemmatopus cristatus, 315.
Strombidinopsis proboscidifer, description of, 50.
Stroudley & Houghton's system of lighting trains, 391.
Stylostoma Forrestii, description of, 48.
Subclavian artery, comparative anatomy of, 311.
Surface condensation in marine engines, 18.
Sutherland, Dr., and intramural interments, 265.
Swan incandescence lamps, life of, 396.
Switzerland, technical schools in, 76.
Table of new apochromatics, 38; search oculars and working oculars, 39.
Tasmanians and Australians compared, 151.
Taxation, local, increase in, 141.
Technical education of workmen in foreign countries, 141.
Technical education, progress of, David Sandeman on, 73.
Technical schools in Belgium, 77; in Canada and the States, 77; in France, 76; in Switzerland, 76.
Temperature for cultivating vaccine lymph, 377.
Tempering of magnets, 43.
Tentaculiferous protozoon (new), and other infusoria, William Milne on, 48.
Thomson, Geo. C., on bursting of leaden service pipes by water and frost, 102.
Thomson, Dr. Thomas, 127.
Thomson, Sir William, on double chain of electrical measuring instruments, 249; on molecular measurement, 132.
Thorpe, Prof. T. E., on certain modern developments of Graham's ideas concerning the constitution of matter, 118.
Tidal currents in Clyde sea-area, 341-344.
Total heat gained and lost in water in Clyde sea-area, 355.
Train-lighting, three methods in use, 391; on Great Eastern, Great Northern, and Lancashire and Yorkshire Railways, 392.
Tribes of New Guinea, some of the, Rev. James Chalmers on, 57.

Underground waters, 71.
Universities of Leipzig, Glasgow, and Edinburgh, number of students in, 327.
Ulfilas, Bishop, brief account of, 208.
Ultimate elements in grammar, 232.

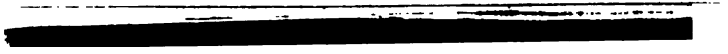
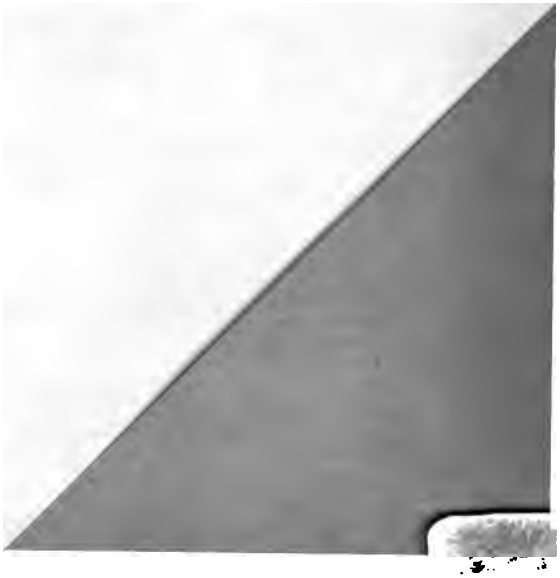
Vaccine lymph experiments, by Chauveau, Burdon Sanderson, and others, 369.
Vaccine lymph, kind to be used as seed in cultivation experiments, 379; cultivations, result of, 380; abortive vesicles, explanation of, 386.
Vaccinia, a specific disease, 370.
Ventral trunk and dorsal trunk arteries in embryonic stage of vertebrates, 303.
Vermiform zooids, 49.
Vertebral artery in crocodile, 313.
Vertebrates, arterial system of, Dr. J. Yule Mackay on, 302.

Walker's "Gatherings from Graveyards," reference to, 257.
Wallace, Dr. William, on gas testing, 91; Welsbach gas-light described by, 427.
Walls, roof, and solum, ownership of, 190.

Waters, underground, 71.
Watt's steam-engine applied in ship propulsion, 5.
Wealth of the country being maintained and increased, 139.
Weapons of Australians, 160.
Weaving department of Glasgow Technical College, 82.
Weaving schools of Germany, 74.
Welsbach gas-light, shown and described by Dr. William Wallace, 427.
Woking Cemetery Company, 267.

Yellow fever, spread of, in Rio Janeiro, 268.
Young's (Dr. James) gift of statue of Graham, 118.

Zoological studies in Leipzig University, 329.
Zooids, vermiform, 49.



Stanford University Libraries
3 6105 124 460 531